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Appendix A

**Stress Induced in Geomembrane and Geosynthetic Clay
Liner**

STRESS INDUCED IN GEOMEMBRANE AND GCL

OBJECTIVE: Estimate the stress induced in the geomembrane and geocomposite clay (GCL) liner due to the self and overlying material weight and subgrade settlement

METHOD: The stress induced in the geomembrane and GCL are due a combination of the weight of the material and the strain applied to the material due to settlement of the underlying layers.

ASSUMPTIONS: Use GSE 60 mil textured HDPE geomembrane and Cetco GCL

CALCULATION:

Self and overlying weight: Based on EDF-ER-268, the minimum interface shear strength for the liner system is 29.3° . The liner system slope angle is 3H:1V (18.4°); therefore, since the interface friction angle is greater than the slope angle, there is no net stress on the liner system.

Settlement:

Minimum horizontal slope length:	85 ft	See page 2, Drawing C-302
Minimum vertical slope length:	28 ft	See page 2, Drawing C-302
Initial three dimensional slope length (l_o):	89.49 ft	
Maximum vertical displacement	1.2 ft	Based on results of EDF-ER-266
Final vertical slope length:	29.2 ft	
Final three dimensional length (l_f):	89.88 ft	
Liner strain $((l_f - l_o)/l_o)$:	0.004258	
	0.425783 %	

HDPE Liner Stress ($s = Ev$)

HDPE Tensile Strength at Yield:	130 lb/in	See specification sheet
HDPE liner thickness:	0.060 in	
HDPE liner elastic modulus:	2,166.667 psi	
Liner stress (s):	9.225299 psi	
Safety Factor (Allowable elastic stress/applied stress):	234.86	

CONCLUSIONS: Based on the calculations, the subgrade settlement will have no detrimental effect on the HDPE liner system.

GCL Liner Stress

Elastic properties for GCL material are not normally determined. A standard physical property specified is grab elongation. Therefore the estimated strain will be compared to the GCL grab elongation.

Estimated strain from above calculation:	0.425783 %	
GCL grab elongation:	50 %	per company representative
Safety Factor (Allowable strain/applied strain)	117.43	

CONCLUSIONS: Based on the calculations, the settlement of the subgrade will have no detrimental effect on the GCL liner system.

Designing for Separation

Solution: (a) Using a maximum strain of 33%, the value of $f(\epsilon)$ required grab tensile strength is as follows:

$$\begin{aligned} T_{\text{reqd}} &= p'(d_s)^2(0.52) \\ &= p'(0.33 d_s)^2(0.52) \\ &= 0.057 p' d_s^2 \\ &= 0.057(100)(2.0)^2 \\ &= 22.6 \text{ lb.} \end{aligned}$$

(b) The global factor of safety on a 125-lb. ultimate grab tensile geotextile with partial factors of safety of 2.5 is as follows:

$$\begin{aligned} FS &= \frac{T_{\text{allow}}}{T_{\text{reqd}}} \\ &= \frac{125/2.5}{22.6} \\ &= 2.2, \text{ which is acceptable.} \end{aligned}$$

2.5.4 Puncture Resistance

Although not only related to the separation function, the geotextile during its placement must survive the installation process. Indeed, fabric survivability is critical in all types of applications; without it, the best of designs are futile (recall Section 2.2.5.1). In this regard, sharp stones, tree stumps, roots, miscellaneous debris, and other things on the ground beneath the geotextile could puncture through the geotextile after stone base and traffic loads are imposed above it. The design method suggested for this situation is shown schematically in Figure 2.29. For these conditions, the vertical force exerted on the geotextile (which is gradually tightening around the protruding object) is as follows:

$$F_{\text{reqd}} = p' d_s^2 S_1 S_2 S_3 \quad (2.30)$$

where F_{reqd} = the required vertical force to be resisted,

p' = the pressure exerted on the geotextile (approximately 100% of tire inflation pressure at the ground surface for small stone thicknesses),

d_s = the average diameter of the puncturing aggregate or sharp object,

S_1 = protrusion factor = h_s/d_s ,

h_s = protrusion height $\leq d_s$,

S_2 = scale factor to adjust ASTM D4833 test value using 5/16-in.-diameter puncture probe to actual puncturing object = $0.31/d_s$,

S_3 = shape factor to adjust flat puncture probe of ASTM D4833 to actual shape of puncturing object = $1 - A_p/A_s$ (values of A_p/A_s to be used

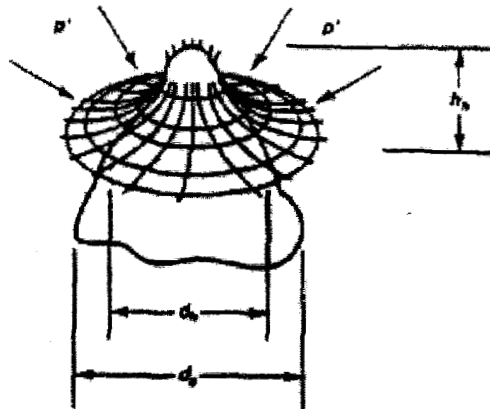


Figure 2.28 Visualization of a stone puncturing a geotextile as pressure is applied from above.

range from 0.8 for Ottawa sand, 0.7 for run-of-bank gravel, 0.4 for crushed rock, and 0.3 for shot rock),
 A_p = projected area of particle, and
 A_c = area of smallest circumscribed circle.

Example:

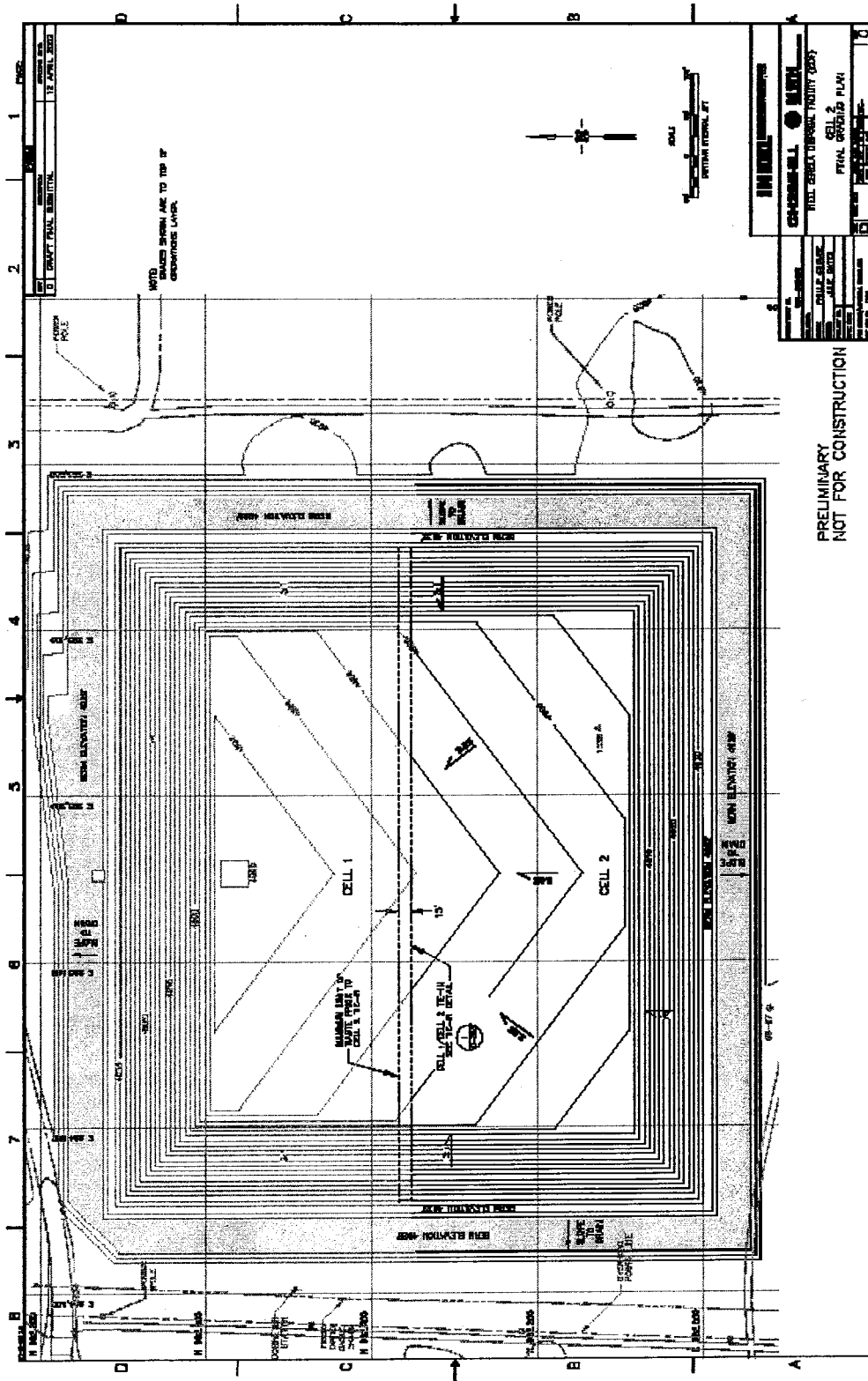
What is the factor of safety against puncture of a geotextile from a 2.0-in. stone by a loaded truck with tire inflation pressure of 80 lb./in.² traveling on the surface of the stone base? The geotextile has an ultimate puncture strength of 45 lb. according to ASTM D4833.

Solution: Using the full stress on the geotextile of 80 lb./in.² and factors of 0.33, 0.155, and 0.6 for S_1 , S_2 , and S_3 , respectively,

$$\begin{aligned} F_{req} &= p' d_s^2 S_1 S_2 S_3 \\ &= 80 \times (2.0)^2 (0.33) (0.155) (0.6) \\ &= 9.82 \text{ lb.} \end{aligned}$$

Assuming that the cumulative partial factor of safety is 2.0, the global factor of safety is as follows:

$$\begin{aligned} FS &= \frac{F_{allow}}{F_{req}} \\ &= \frac{45/2.0}{9.82} \\ &= 2.3, \text{ which is acceptable.} \end{aligned}$$



(See Drawing C-302 of the ICDF Draft Final Drawings for details)

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ENGINEERING DESIGN FILE

Functional File No. NA
EDF No. ER-268

1. Project File No.: NA 2. Project/Task: ICDF
3. Subtask: Slope Stability Assessments

4. Title: Slope Stability Assessments (Title I)

5. Summary:

This report documents the slope stability evaluations that were performed to aid in the design of the liner system for the ICDF landfill and ICDF evaporation pond. These stability evaluations included veneer stability, global stability, and stability after excavation. Veneer stability involves evaluation of the potential for sliding of the drainage layer on the liner system before refuse is placed. Global stability involves evaluation of the potential for sliding during operation of the landfill and of the stability of the final landfill configuration with the cover in place. Stability after excavation involves evaluation of stability, immediately after excavation of the landfill and before placement of the lining system.

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Distribution (summary package only):

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For veneer stability of the lining system, strength values based on test data conducted under low normal stresses were considered appropriate. For this project, low normal stress—in the context of veneer stability—was limited to stress levels less than 600 pounds per square foot (psf), or an equivalent of up to about 5 ft of soil. Interface shear strength data applicable to this stress level were then modeled using linear regression. In the regression analysis, the interface shear strength was represented by an effective friction angle by forcing the cohesion intercept to zero. The idea of using the effective friction angle to represent the shear strength of the interface at low normal stress is to maintain the magnitude of the shear strength while eliminating the dependency on the cohesion intercept in the strength parameter determination. For low effective confining pressures, this approach allows the shear strength to approach zero as confinement goes to zero.

Appendix A contains the database of interface shear strength tests that were analyzed. Material interfaces in which test data has been analyzed under this task include soil/geocomposite, textured HDPE/geocomposite, textured HDPE/GCL, and GCL/geocomposite interface. Based on the measured and reported interface strength data, peak and residual strengths of lining material interfaces were evaluated. For veneer stability analysis, however, residual strengths are considered to be appropriate (Stark and Poeppel 1994). For the soil/geocomposite interface shear strength, test data that indicate a mixture of sand and gravel (with and without silt) for the soil component, consistent with the description of the on-site native material, were evaluated in the analyses. Shear strength data for CCL/textured HDPE interface were not analyzed due to the inadequate amount of data that is available. In the absence of adequate data, test results from the Cedar Hills Regional Landfill (CHRL) project (CH2M HILL 1998a) were used in the analyses. These results indicate an interface friction angle of about 25 degrees and a cohesion of zero for the CCL/HDPE interface. Additional site-specific testing is recommended to confirm this value, as discussed in "Evaluation of Geotechnical Investigations and Calculations Required to Complete Design and Construction" (DOE-ID 2001b). Results of site-specific interface shear testing will be reported in the 90% Remedial Design/Remedial Action (RD/RA) design submittal. Analyses presented herein will be revised if lower strength values are obtained from the site-specific testing.

Based on the above evaluations, the critical interface for the veneer stability analysis appears to be the non-woven GCL/non-woven geocomposite interface. A residual friction angle of 19 degrees was developed from the existing data for low normal stress for this interface. Most recent test results provided by Montgomery Watson (1999) using exactly the same materials proposed for this project, except that the woven side of GCL was used, indicate an effective residual interface friction angle of 24 degrees. In this project, it is proposed that a non-woven side of GCL will be placed in contact with the geocomposite, which, as a result, could yield a higher residual friction angle than the 24 degrees that was reported. For this reason, and the fact that actual test results are available for the proposed lining material, it was decided to use a residual friction angle of 24 degrees for the GCL/geocomposite interface. This value matches the residual interface friction angle for the HDPE/geocomposite interface as the most critical interface for veneer stability. It is recommended, however, that actual interface shear strength tests be conducted for the non-woven GCL/non-woven geocomposite interface to confirm this value. Results of site-specific interface shear testing will be reported in the 90% RD/RA design submittal. Analyses presented herein will be revised if lower strength values are obtained from the site-specific testing.

The analysis for self-weight (Case 1) involved an evaluation of veneer stability under the load of the 3-ft-thick operations layer only. For equipment loads (Case 2), an equivalent equipment weight of 4,400 pounds per lineal foot of lining system such as that caused by a D6H Caterpillar dozer was assumed during placement of the drainage layer over the HDPE geomembrane. It was further assumed for this loading case that the seepage height would be zero. For the seepage case (Case 3), the maximum allowable head over the side slope lining system is 6 in. for stability purposes. FSs corresponding to seepage heights of 3 in. and 6 in. were evaluated. A maximum slope height of 40 ft was used in running the SLOPBASE program.

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ENGINEERING DESIGN FILE

Functional File No. NA
EDF No. EDF-ER-266

1. Project File No.: NA 2. Project/Task: ICDF
3. Subtask: Subsurface Consolidation Calculation

4. Title: Subsurface Consolidation Calculation				
5. Summary: The purpose of this calculation is to determine the maximum consolidation in the landfill foundation soils resulting from the load of the waste material and cover. The maximum amount of consolidation is used to determine the differential settlement and integrity of the landfill liner system.				
6. Distribution (complete package): M. Doombos, MS 2930 D. Vernon, MS 3930 T. Borschel, MS 3930 Distribution (summary package only):				
7. Review (R) and Approval (A) Signatures: (Minimum reviews and approvals are listed. Additional reviews/approvals may be added.)				
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Independent Reviewer	R	Phillip Crouse/Montgomery Watson		
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6. RESULTS AND CONCLUSIONS

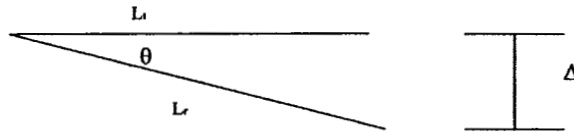
6.1 Maximum Differential Settlement

The maximum total settlement at the center of the landfill is conservatively estimated to be 1.2 ft. * Differential settlement is a function of the maximum total settlement and will be less than the total settlement; however, it is difficult to estimate. So, as a worst case, the maximum differential settlement is assumed to be equal to the maximum total settlement of 1.2 ft.

6.2 Stress and Strain in Liner Components

As the bottom of the liner consolidates, it will distort creating strain in each of the liner components. Assuming all the settlement occurs near the center of the landfill and no settlement occurs on the ends, the maximum differential settlement will be 1.2 ft as described previously. The floor of the landfill in its shortest direction is approximately 528 ft. (EDF 265 – Air Space Volume Calculation. The resulting strain is calculated below:

$$\varepsilon = \frac{L_f - L_i}{L_i}$$



Where,

ε = Strain

L_f = Final length

L_i = The length on which the distortion acts

θ = Angle of rotation

Δ = Distortion

Using half of the width of the landfill, the maximum amount of strain is 0.001%. The calculation is presented below:

$$L_i = \frac{528 \text{ ft}}{2} = 264 \text{ ft}$$

$$\theta = \sin^{-1} \left(\frac{1.2 \text{ ft}}{264 \text{ ft}} \right) = 0.26$$

$$L_f = 264 \frac{264 \text{ ft}}{\cos(0.39)} = 264.003$$

$$\varepsilon = \frac{264.004 \text{ ft} - 264 \text{ ft}}{264 \text{ ft}} = \frac{0.003 \text{ ft}}{264 \text{ ft}} \times 100 = 0.001\%$$



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GSE
HyperFrictionFlex
Textured HyperFlex
HDPE Geomembrane

GSE HyperFrictionFlex is a premium grade, high density polyethylene (HDPE) geomembrane produced from a specially formulated, virgin polyethylene resin, and textured using GSE's patented FrictionFlex® process. The polyethylene resin is designed specifically for flexible geomembrane applications. HyperFlex has outstanding resistance to UV radiation and stress cracking and is therefore highly suited for exposed applications. The FrictionFlex process is the only manufacturing method that provides a textured material without significant reduction of any of the physical properties of the smooth surfaced membrane. No other textured membrane provides an equivalent combination of enhanced slope stability and resistance to containment failure if settlement of the lined structure occurs.

TESTED PROPERTY	TEST METHOD	MINIMUM VALUES			
Thickness, mils (mm)	ASTM D 751/1593/5199	36 (0.90)	54 (1.35)	72 (1.80)	90 (2.25)
Density, g/cm ³	ASTM D 792/1505	0.94	0.94	0.94	0.94
Tensile Properties (each direction)	ASTM D 638, Type IV				
Strength at Break, lb/in-width (N/mm)	Dumbell, 2 ipm	162 (28)	243 (43)	324 (57)	405 (71)
Strength at Yield, lb/in-width (N/mm)		86 (15)	130 (23)	173 (30)	216 (38)
Elongation at Break, %	G.L. = 2.5 in (64 mm)	500	560	560	560
Elongation at Yield, %	G.L. = 1.3 in (33 mm)	13	13	13	13
Tear Resistance, lb (N)	ASTM D 1004	30 (133)	45 (200)	60 (267)	75 (334)
Puncture Resistance, lb (N)	FTMS 101, Method 2065	52 (231)	80 (356)	105 (467)	130 (579)
Carbon Black Content, %	ASTM D 1603	2.0	2.0	2.0	2.0
Environmental Stress Crack Resistance, hr	ASTM D 1693, Cond. B	1500	1500	1500	1500
REFERENCE PROPERTY	TEST METHOD	NOMINAL VALUES			
Thickness, mils (mm)	ASTM D 751/1593/5199	40 (1.0)	60 (1.5)	80 (2.0)	100 (2.5)
Roll Length (approximate), ft (m)		665 (216)	470 (215)	350 (107)	280 (85)
Low Temperature Brittleness, °F (°C)	ASTM D 746, Cond. B	<-107 (<-77)	<-107 (<-77)	<-107 (<-77)	<-107 (<-77)
Oxidative Induction Time, minutes	ASTM D 3895, 200 °C Pure O ₂ , 1 atm	100	100	100	10
Carbon Black Dispersion	ASTM D 3015	A1,A2,B1	A1,A2,B1	A1,A2,B1	A1,A2,B1
Dimensional Stability (each direction), %	ASTM D 1204, 100 °C, 1 hr	±2	±2	±2	±2
Melt Flow Index, g/10 minutes	ASTM D 1238, Cond.190/2.16	≤1.0	≤1.0	≤1.0	≤1.0

GSE HyperFrictionFlex is available in rolls approximately 22.5 ft (6.9 m) and 24 ft (7.3 m) wide and weighing about 3,500 lb (1,588 kg). Other material thicknesses are available upon request. See the FrictionFlex Application Data Sheet for more information regarding the GSE FrictionFlex texturing process.

** Roll lengths correspond to the 24 ft (7.3 m) wide roll goods.

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DS 002 R03/04/98

Appendix B
Geotextile Puncture Resistance

Required Puncture Resistance of Geotextile

OBJECTIVE: Determine the puncture resistance of the cushion geotextile required to prevent puncturing of the geomembrane by gravel layer

METHOD: The cushion geotextile is intended to protect the geomembrane from punctures caused by the gravel layer above the geomembrane. The required puncture resistance for the cushion geotextile will be dictated by the largest particle diameter for the gravel layer under the force provided by the waste and cover system above. The required puncture resistance was solved for using the formula presented in "Designing with Geosynthetics" 3rd edition, Koerner, 1995, pg 165 (see page 5 of this appendix). The formula is given below.

$$F_{req} = p' \cdot d_a^2 \cdot S_1 \cdot S_2 \cdot S_3$$

F_{req} - required vertical force to be resisted

p' - pressure exerted on geotextile

d_a - average diameter of puncturing aggregate

S_1 - protrusion factor, h_p/d_a

h_p - protrusion height $\leq d_a$

S_2 - scale factor to adjust ASTM D4833 test value using 5/16" diameter rod to the actual puncturing object = d_{probe}/d_a

d_{probe} - probe diameter which is 5/16" for ASTM D4833

S_3 - shape factor to adjust test puncture probe of ASTM D4833 to actual shape of puncturing object = $1 - A_p/A_c$
(values range from 0.8 for round sand, to 0.7 for run-of bank gravel, to 0.4 for crushed rock, to 0.3 for shot rock)

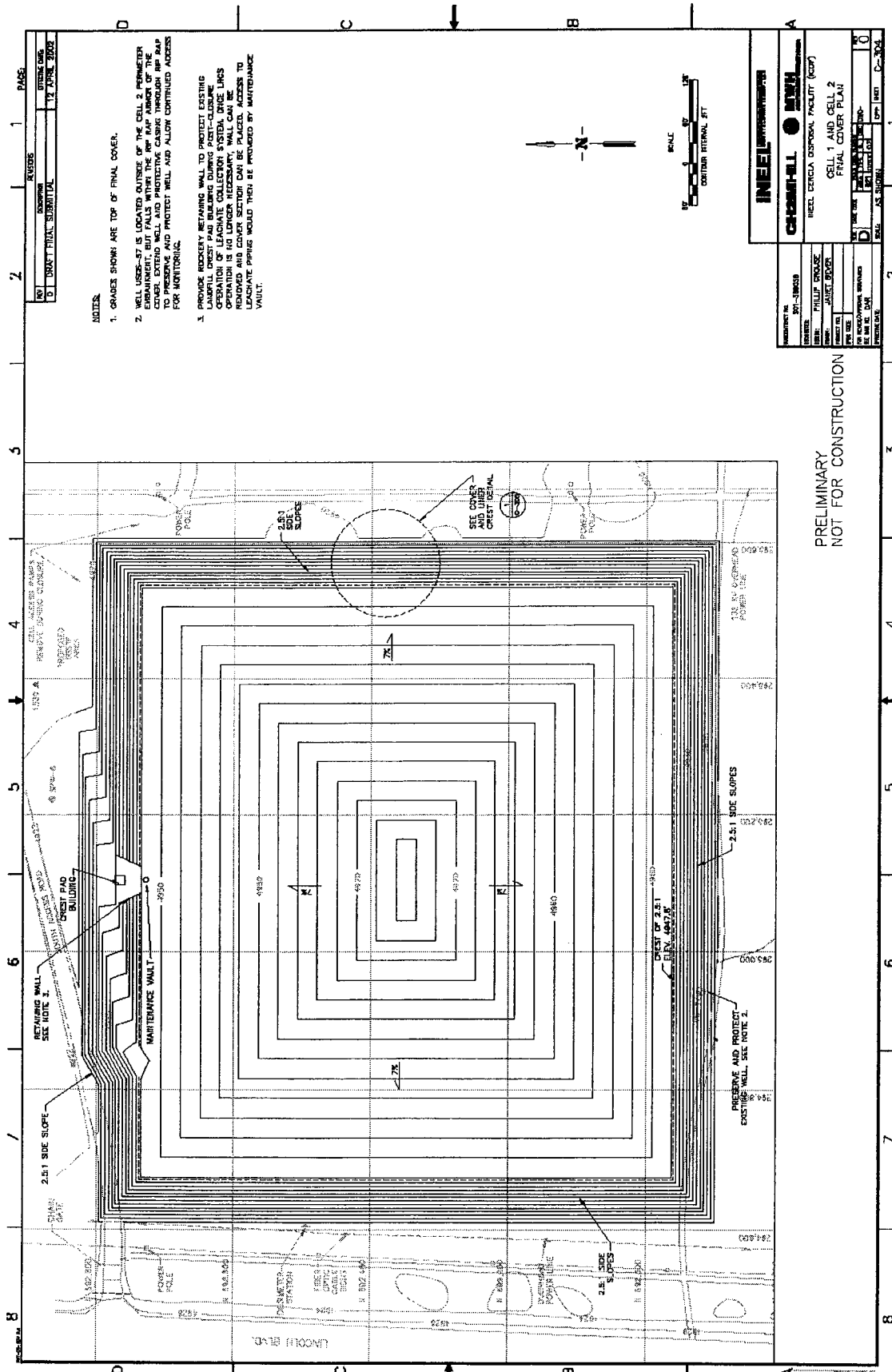
A_p - projected area of particle

A_c - area of smallest circumscribed circle

Calculation:

Maximum elevation of cover system:	4974 ft	See pg 2 drawing C-304
Minimum elevation of liner system:	4884 ft	See pg 3 drawing C-301
Maximum waste thickness:	90 ft	
Estimated waste density:	133.5 pcf	from EDF-ER-266
Average aggregate diameter (d_a):	0.67 in	17mm = 0.67 in for Gravel D ₅₀
Probe diameter (d_{probe}):	0.3125 in	
A_p/A_c ratio:	0.4	conservate assumption, see pg. 5
Maximum anticipated pressure on the liner system (p'):	83 psi	
Protrusion factor (S_1):	0.50	assume $h_p = 0.5 d_a$
Scale factor (S_2):	0.47	
Shape fator (S_3):	0.6	
F_{req} :	5.2 lbs	

	Installation Damage	Creep	Chemical Degradation	Bio Degradation
Typ Cushion Reduction Factors Ranges (Koerner,p. 149)	1.1 to 2.5	1.5 to 2.0	1.0 to 2.0	1.0 to 1.2
Reduction Factors Used:	2	2	1.5	1.1
Total RF:	6.6			
Geotextile Specified Puncture Resistance:	135 lbs			
F_{allow} :	20.5 lbs			
$FS = F_{allow}/F_{req}$:	3.9			



(See Drawing C-303 in the ICDP Draft Final Drawings for further detail.)

Safety Factor Against Geomembrane Puncture - Design Calculator

① uses $MF_s = 0.5 \rightarrow$ more conservative than EPA
 ② uses $H = 15 \text{ mm} = 0.015 \text{ m}$

Problem Statement

There are many circumstances where geomembranes are placed on or beneath soils containing relatively large-sized stones. For example, poorly prepared soil subgrade with stones protruding from the surface, and cases where crushed-stoned drainage layers are to be placed above the geomembrane.

← conservative than EPA

In all of these situations, a nonwoven needle-punched geotextile can provide significant puncture protection to the geomembrane. The issue of determining the required mass per unit area of the geotextile becomes critical.

③ uses only RF_{CR} and RF_{CBD}

The method presented herein (Koerner, 1998) focuses on the protection of 1.5 mm thick HDPE geomembranes. The method uses the design by function approach.

factor by

$$FS = \frac{P_{allow}}{P_{act}}$$

where:

FS factor of safety against geomembrane puncture
 P_{act} actual pressure due to the landfill contents or surface impoundment
 P_{allow} allowable pressure using different types of geotextiles and site specific conditions.

P_{allow} is determined by the following equation:

$$P_{allow} = \left(50 + 0.00045 \frac{M}{H^2} \right) \left[\frac{1}{MF_s * MF_{PD} * MF_A} \right] \left[\frac{1}{RF_{CR} * RF_{CBD}} \right]$$

where:

Symbol	Name	Unit
P_{allow}	allowable pressure	kPa
M	geotextile mass per unit area	g/m ²
H	height of the protrusion above the subgrade	m
MF_s	modification factor for protrusion shape	-
MF_{PD}	modification factor for packing density	-
MF_A	modification factor for arching in solids	-
RF_{CR}	reduction factor for long-term creep	-
RF_{CBD}	reduction factor for long-term chemical/biological degradation	-

Appendix C

Geomembrane Wind Lift Analysis

Evaporation Pond Wind Lift Analysis

OBJECTIVE: Determine the necessary anchorage to negate HDPE geomembrane movement due to the wind in the evaporation pond. Determine this for both short and long term conditions.

METHOD: Use design tables from Koerner and Wayne, *Effect of Wind Uplift on Liner Systems*, Geosynthetic Fabrics Report, July/August 1988. A wind speed of 70 mph will be used based on EDF-ER-323, Evaporation Pond Berm Overtopping Analysis, which used this value to calculate wave runup within the evaporation pond.

ASSUMPTIONS: Sand bags are assumed to be 70 lbs each (minimum)

CALCULATIONS:

Short Term: Sand bags will need to be placed on top of the geomembrane liner after installation because the geomembrane is the upper most layer in the evaporation pond liner system.

The short term wind speed of 35 mph was used which is approximately half of 70mph which is the upper end of wind speed gusts measured.

Based on attached Figures 3 - 10, the average C_p (pressure coefficient) is -0.2

Use Table 2(b), and a C_p value of -0.2 to determine sand bag spacing,

25 mph wind - 1 sand bag per 219 ft²
50 mph wind - 1 sand bag per 54.8 ft²

Using linear interpolation of these values to determine the area per sand bag for a 35 mph wind, one sand bag should be placed for every 153 square feet.

Sand bags should be tied off every 5 linear feet along the rope. To determine the bag line spacing, divide 153 square feet by 5 feet.

Sand Bag Line Spacing = 153 sq. ft / 5 ft = 30.6 ft or approximately 30 feet

Long Term:

A long term wind speed of 45 mph was used which is approximately 65% of 70 mph which is the upper end of wind speed gusts measured.

Based on attached Figures 3 - 10, the average C_p (pressure coefficient) is -0.2

Use Table 2(b), and a C_p value of -0.2 to determine sand bag spacing,

25 mph wind - 1 sand bag per 219 ft²
50 mph wind - 1 sand bag per 54.8 ft²

Using linear interpolation of these values to determine the area per sand bag for a 45 mph wind, one sand bag should be placed for every 86.2 square feet.

Sand bags should be tied off every 5 linear feet along the rope. To determine the bag line spacing, divide 86.2 square feet by 5 feet.

Sand Bag Line Spacing = 153 sq. ft / 5 ft = 17.2 ft or approximately 15 feet

For long term conditions, in addition to sand bagging it is suggested that the bottom of the pond be covered with a minimum of either soil or fluid in the bottom to counterweight additional long term uplift pressures due to wind.

Conclusion: For short term conditions, sand bags should be placed at a 30 feet spacing. For long term conditions, sand bags should be placed every 15 feet and either fluid or soil should be placed in the bottom.

Effect of Wind Uplift on Liner Systems

The installation of geomembrane liner systems for reservoirs, landfills and other related impoundments is greatly affected by wind. Natural winds near the earth's surface are influenced by friction at the ground surface and turbulence within the flowing air mass. Uplift forces develop as a result of wind flow separation, which occurs when the air mass decelerates or when boundary shapes are irregular. Downstream from the point of air flow separation, a disturbed flow, or wake of turbulent eddies is formed and flow reverses. When such uplift forces are not adequately resisted by (a) dead weight (sandbags, tires, etc.), (b) suction devices (installation of suction cows as used in the agricultural industry) or (c) permanent bonding (e.g., placement of an asphalt emulsion) methods, various stresses on the geomembrane sheets and seams are exerted. In the limit they will lift the sheet, and/or cause tearing to occur.

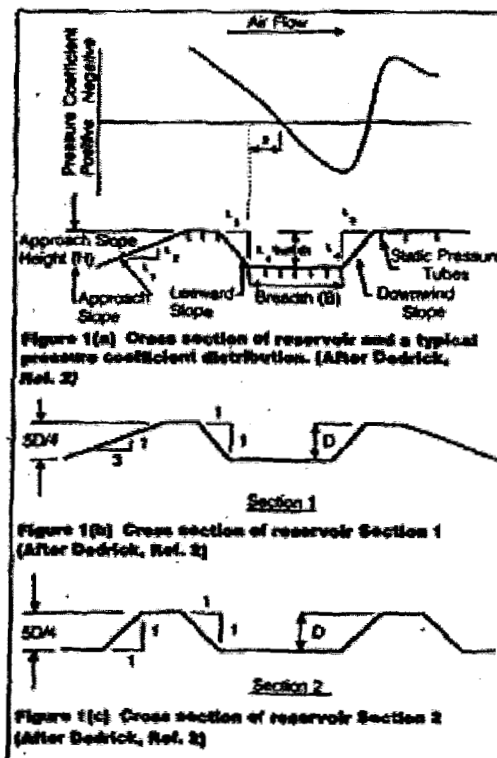
Discussion

This brief paper uses information obtained by Dedrick^{1,2} to develop a design methodology that can be used in determining the magnitude and distribution of tractive (uplift) forces on geomembrane systems. In particular the paper focuses on two reservoir sections with the following geometric characteristics, (see Figures 1(a-c)).

Geometric Detail	Section 1 [fig. 1(b)]	Section 2 [fig. 1(c)]
Approach Slope	1:3	1:1
Approach-Slope Height	SD/4	SD/4
Leeward Slope	1:1	1:1
Breadth-to-Depth Ratio	5	5

Dedrick^{1,2} highlights the required fluid mechanics principles relative to modeling of water-harvesting catchments and reservoirs for agricultural purposes. This same information can be applied to solid waste land disposal cells and surface impoundments during construction and prior to filling that have site geometry similar to the previously mentioned sections.

Figure 1(a) illustrates the geometric configuration of the sections studied and also indicates pressure measurement locations for the various sections examined. In Dedrick's study each model section was subjected to test wind velocity ranges of 92 to 96, 126 to 130, and 157 to 160 mph. Additionally, airflow was varied from 0° (which was parallel



Through proper dimensional analysis, Dedrick^{1,2} formed the following dimensionless equation.

$$C_p = \frac{\Delta P}{1/2 \rho V^2} \quad (\text{Eq. 1})$$

Where

C_p = pressure coefficient
 ΔP = pressure difference (lb/ft²)
 ρ = fluid density (slug/ft³) = lb/ft³/g
 V = air velocity (ft/sec)

(a) Traction (uplift) forces, in lb/ft ² , produced at various wind speeds as listed with C values found in Figures 3-10.					
Wind Speed →	25 mph	50 mph	75 mph	100 mph	125 mph
Cp Values					
-0.2	0.32	1.28	2.88	5.11	8
-0.4	0.64	2.56	5.75	10.2	16
-0.6	0.96	3.83	8.63	15.3	24
-0.8	1.28	5.11	11.5	20.5	32
-1	1.6	6.39	14.4	25.6	40

Table 2(b) Sandbag spacing requirements in ft, necessary to compensate for the uplift forces found in Table 2(a).

Wind Speed →	25 mph	50 mph	75 mph	100 mph	125 mph
Cp Values					
-0.2	219	54.8	24.3	13.7	8.8
-0.4	109.5	27.4	12.2	6.8	4.4
-0.6	73	18.3	8.1	4.6	2.9
-0.8	54.8	13.7	6.1	3.4	2.2
-1	43.8	11	4.9	2.7	1.8

value of uplift pressure can then be resisted by whatever mechanism is available, e.g., tires or sandbags.

To illustrate use of the preceding information, we have developed example design tables and an illustrative problem. Table 2(a) has been developed on the basis that air density is conservatively taken at sea level ($\rho = 0.002377$ slug/ft³) and wind speeds are taken as 25, 50, 75, 100, and 125 mph. Calculated sandbag spacings were based on the use of 70 lb sandbags and are presented in Table 2(b).

Note that these sandbag spacing are not required over the entire site but only where negative values of C exist. Thus for the section illustrated in Figure 3, with a design wind velocity of 75 mph, uplift pressures will develop as shown in Figure 11(a). To resist such forces, sandbags weighing 70 lb each would be required as shown in Figure 11(b).

Conclusion

The problem of wind forces lifting up liners and occasionally tearing them and/or their seams, is addressed in this short paper. While its major focus is toward geomembranes, other geosynthetics have experienced wind-related construction problems. For example, geotextiles used to retard reflective cracking in highway rehabilitation and geotextiles used on slopes for erosion control systems have been known to be problematic in high wind locations. The techniques presented should apply to these situations as well as with geomembranes.

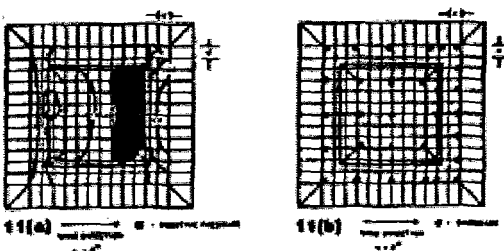


Figure 11(a) Induced uplift pressure, in psf, produced by 75 mph winds. (b) Sandbag spacing required for geomembrane system illustrated in (a). Note that dimensions are exaggerated for illustrative purposes.

References

1. Dedrick, A. R., Air Pressures Over Surfaces Exposed to Wind. I. Water Harvesting Catchments, TRANSACTIONS of the ASAE, Vol. 17, No. 5, 1974.
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3. Richardson, G. N. and Koerner, R. M., Geosynthetic Design Guidance for Hazardous Waste Landfill Cells and Surface Impoundments, United States Environmental Protection Agency, Contract No. 68-03-3338.
4. Fox, R. W. and McDonald, A. T., Introduction to Fluid Mechanics, 3rd ed., John Wiley and Sons, New York, 1965.

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Appendix D

Anchor Trench Pullout Resistance Calculation

ANCHOR TRENCH PULL OUT RESISTANCE CALCULATION

Objective: Determine Anchor Trench Pull Out Resistance

Input:

Minimum Liner interface friction angle (d):	29.3 °	(Nonwoven GCL/composite drainage net, see attached shear strength information from EDF-ER-268)
Minimum Liner interface adhesion (a):	0 psf	(Nonwoven GCL/composite drainage net, see attached shear strength information from EDF-ER-268)
Cover Soil Density (G_{cs}):	120 pcf	
Anchor Trench Soil Density (g):	110 pcf	
Anchor Trench Width (L_{AT}):	2 ft	
Anchor Trench Depth (d_{AT}):	2 ft	
Operations Layer Thickness (d_{cs}):	3 ft	
Runout Trench Length (L_{RO}):	3 ft	
Anchor Trench Backfill Friction Angle (f):	30 °	

Anchor Trench Runout Resistance

$$Pr_1 = (s_{n1} \tan d + a) L_{RO}$$

$$s_{n1} = G_{cs} d_{cs}$$

$$s_{n1} = 360 \text{ psf}$$

$$Pr_1 = 606.068 \text{ lbs/ft}$$

Anchor Trench Bottom Resistance

$$Pr_2 = (s_{n2} \tan d + a) L_{AT}$$

$$s_{n2} = (G_{cs} d_{cs}) + (g d_{AT})$$

$$s_{n2} = 580 \text{ psf}$$

$$Pr_2 = 650.96 \text{ lbs/ft}$$

Anchor Trench Sidewall Resistance

$$k_o = (1 - \sin f)$$

$$k_o = 0.5$$

$$s_{havg} = k_o \cdot s_{avgv}$$

$$s_{havg} = 235 \text{ psf}$$

$$s_{havg} = s_{n3}$$

$$Pr_3 = (s_{n3} \tan d + a) d_{AT}$$

$$Pr_3 = 263.75 \text{ lbs/ft}$$

Average normal stress through anchor trench

$$s_{avgv} = (s_{n1} + s_{n2})/2$$

$$s_{avgv} = 470 \text{ psf}$$

Total Anchor Trench Pullout Resistance

$$Tr = Pr_1 + Pr_2 + Pr_3$$

$$Tr = 1520.78 \text{ lbs/foot}$$

Conclusion:

Anchor trench pullout capacity of 1521 lb/ft is greater than the 440 lb/ft that is required to maintain a slope stability safety factor for Case 1 presented in EDF-ER-268. This case is discussed in EDF-ER-268.

ICDF - Interface Strength Values for Veneer Stability Analysis
(EDF-ER-268, Section 3)

Lining System Interface	Strength calc. from regression analysis ^a	Site-Specific Test Results ^b		
	Friction Angle (deg)	Friction Angle (deg)	Apparent Cohesion (psf)	Effective Friction Angle ^c (deg)
Ops Soil/Composite Drainage Net (CDN)	38.0	38.6	86	44.5
CDN/Textured HDPE	24.0	17.8	220	37.5
Textured HDPE/GCL	26.0	27.6	279	47.0
GCL/CDN	19.0 ^d	29.3	0	29.3
Textured HDPE/CCL (Soil-Bentonite) ^f	25.0 ^e	30.8	129	40.7

Notes:

^a - See regression graphs in Appendix A, EDF-ER-268; cohesion = 0 psf in regression analysis

^b - Testing by Precision Geosynthetics (6/01) on site-specific lining materials; normal stress - 100, 250 and 500 psf

^c - Calculated at normal stress of 500 psf with Cohesion = 0 psf

^d - 19 deg calc from data, however 24 deg (based on MW tests) used in analysis; see p. 3.3 in EDF-ER-268

^e - from CHRLF data (1998) see p. 3.3 in EDF-ER-268

^f - Site-specific test data on Soil-bentonite compacted to 87% modified; tests currently being rerun at 92%

Appendix E

Water Erosion of Final Cover Surface

WATER EROSION OF SOIL COVER

OBJECTIVE: Determine the cover soil erosion due to surface sheet erosion.

METHOD: The Modified Universal Soil Loss Equation (MUSLE) was used to calculate the average annual soil erosion resulting from sheet flow across the top surface of the final cover. This is the method presented in NUREG/CR-4620 for use at uranium mining tailing impoundments with a 1000 year design life. This method estimates runoff based on rainfall intensity, soil type, length and slope of the surface, and a control factor which represents vegetative and mechanical factors. The equation is given below.

$$A = R \cdot K \cdot LS \cdot VM$$

where:

A = the computed loss per unit area in tons per acre per year with the units selected for K and R properly selected

R = the rainfall factor which is the number for rainfall erosion index units plus a factor for snowmelt, if applicable

K = the soil erodibility factor, which is the soil loss rate per erosion index unit for a specified soil as measured on a unit plot that is designed as a 72.6 foot length of uniform 9% slope continuously maintained as clean tilled fallow

LS = the topographic factor, which is the ratio of soil loss from the field slope length to that from a 72.6 foot length under other wise identical conditions.

VM = the dimensionless erosion control factor relating to vegetative and mechanical factors. This factor replaces the cover management factor (C) and the support factor (P) of the original USLE.

CALCULATIONS:

Ryegrass Flats and WRRTF Borrow Soil Areas
(see attached particle size distribution)

Ryegrass Flats and WRRTF Borrow Soil Areas
(see attached particle size distribution)

Sample #	Percent silt and very fine sand
#1-O	94
#1-O,#2	93
#1-P,#1	80
#1-P,#2	95
#1-Q,#1	94
#1-Q,#2	96
#3-O,#1	58
#3-O,#2	90
#3-P,Alt. #1	90
#3-P, Alt. 2	92
#3-Q,#1	92
#3-Q,#2	80
Maximum	96
Average	87.83

Sample #	Percent Sand (0.1 - 2.0 mm)
#1-O	6
#1-O,#2	7
#1-P,#1	20
#1-P,#2	5
#1-Q,#1	6
#1-Q,#2	4
#3-O,#1	42
#3-O,#2	10
#3-P,Alt. #1	10
#3-P, Alt. 2	8
#3-Q,#1	8
#3-Q,#2	20
Maximum	42
Average	12.17

K = 0.7 (use attached nomograph to determine K)

R = 20 (use attached figure 5.3 to determine R)

$$LS = \frac{650 + 450s + 65s^2}{10,000 + s^2} \cdot \frac{L}{72.6}$$

where:

s = slope steepness in percent

m = exponent dependent upon slope steepness

L = slope length in feet

s = 7 (see attached drawing)

m = 0.5 (see attached Table 5.2)

L = 434 ft (see attached drawing)

LS = 2.077623

VM = 0.18 (average of seeding values shown in table 5.3)

$$A = 5.235609 \text{ tons per acre per year}$$

Determine the thickness of cover erosion per year.

Assume the density of the cover soil is 110 pcf

Erosion = 0.002185 ft per year

Design Life Erosion = 2.185328 ft per 1000 years
26.22 in per 1000 years
66.61 cm per 1000 years

CONCLUSION: Overbuild the cover thickness by at least 73 cm to compensate for the erosion estimated over the 1000 year landfill service life.

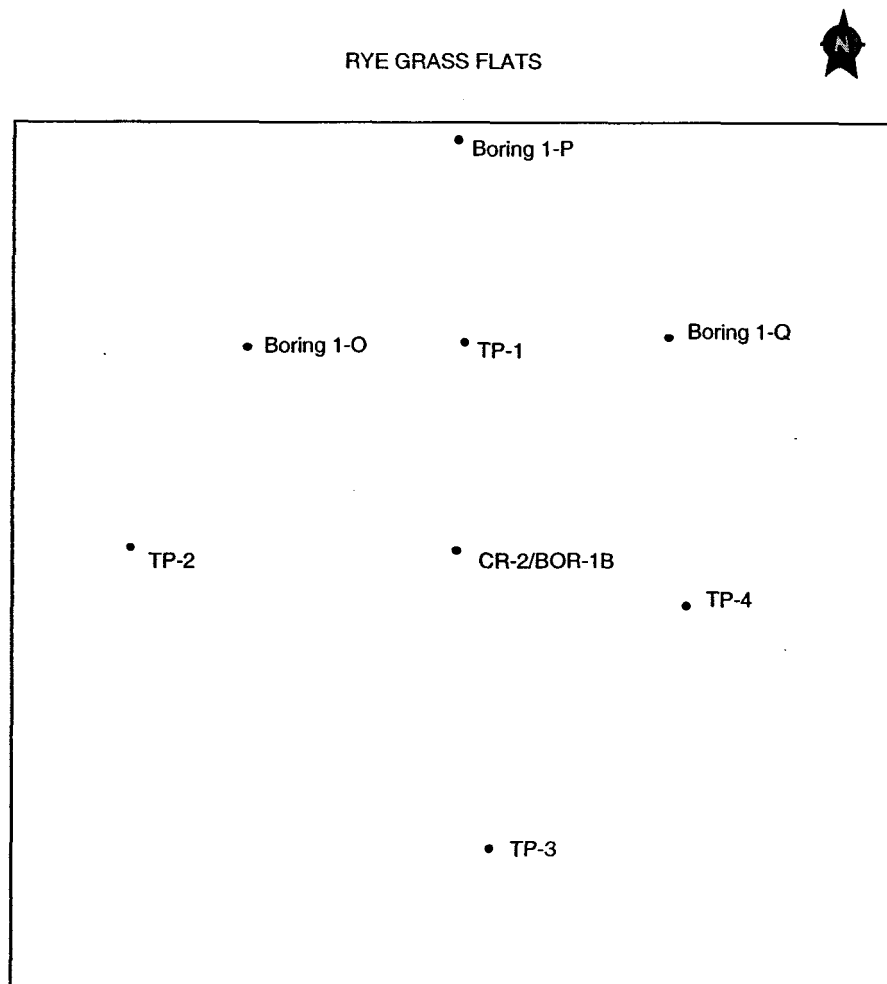


Figure 4-4. Rye Grass Flats boring and test pit locations.

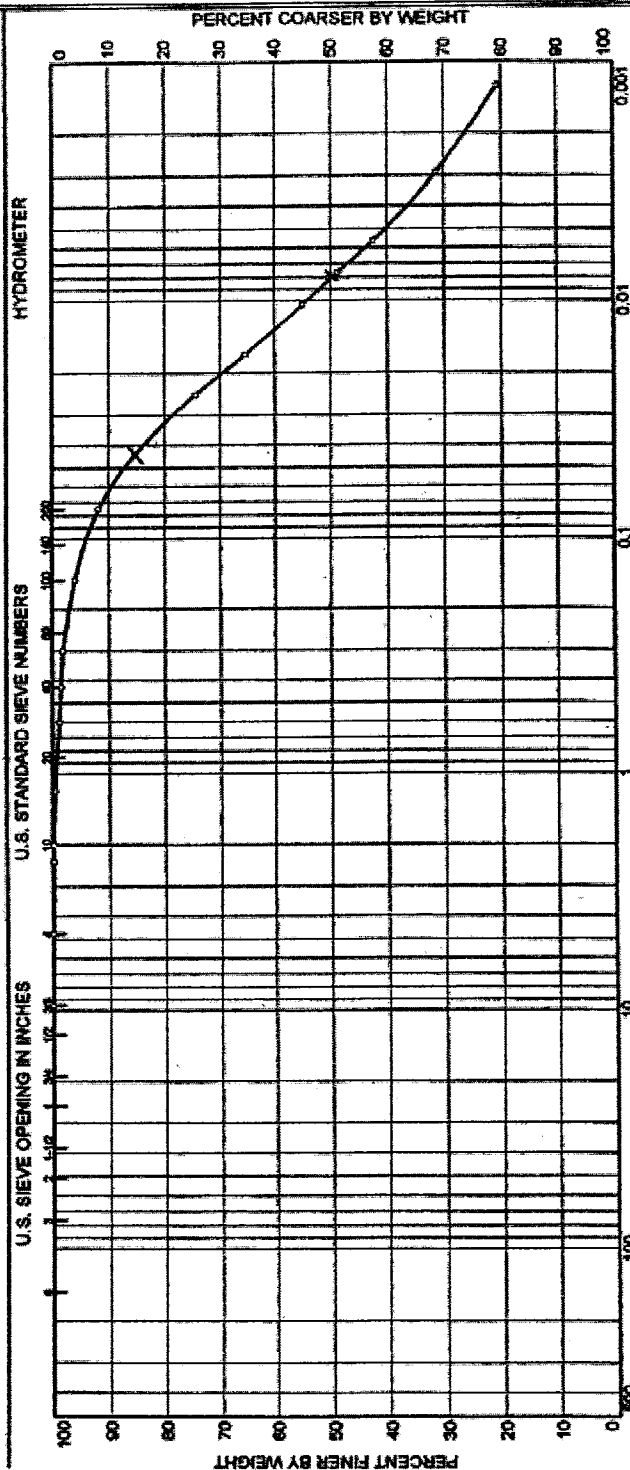
Table 4-1. (continued).

Boring/ Sample	Depth	3" %>	% Gravel			% Sand			% Fines			Mucial Description	Max Dry Density	Opt. Moist %	USCS	NM %	LL	PL	Hydraulic Conductivity	
			Coarse	Fine	Course	Med	Fine	Silt	Clay											
Rye Grass Flats Site																				
1-O #1	2'-2'- 6"	0.0	0.0	0.1	0.1	1.3	6.6	51.6	40.3	Lean clay	106 pcf	18%	CL	10.4	33	18	@ 1'-6"-4'	5.23E-08 cm/sec	Compaction 98.2% Moisture content 16.3%	
1-O #2	6'-7'	0.0	0.0	0.0	0.0	0.1	7.3	43.6	49.0	Lean clay	105 pcf	20%	CL	11.3	33	16	@ 6'-8'	3.02E-07 cm/sec	Compaction 98.8% Moisture content 20.8%	
1-P #1	2'-6"- 3'-6"	0.0	0.0	0.0	0.2	6.1	15.8	44.6	33.3	Lean clay with sand	111 pcf	16%	CL	9.2	28	18	Not tested			
1-P #2	7'-8'	0.0	0.0	0.3	0.2	1.3	4.2	47.3	46.7	Lean clay	107 pcf	19%	CL	11.4	38	17	Not tested			
1-Q #1	2'-3'	0.0	0.0	0.0	0.1	1.2	5.8	37.5	53.4	Lean clay	104 pcf	19%	CL	12.7	44	16	@ 1'-3'	1.40 E-07 cm/sec	Compaction 98.6% Moisture content 18.1%	
1-Q #2	5'-6'	0.0	0.0	0.3	0.4	0.6	3.4	39.4	53.9	Lean clay	110 pcf	20%	CL	12.6	36	19	@ 4'-6"-6'	2.35 E- 06 cm/sec	Compaction 97.5% Moisture content 14.7%	

Table 4-1. Borrow source geotechnical test results.

Table 4-1. Downhole geotechnical test results.																							
Boring/ Sample	Depth	%> 3"	% Gravel					% Sand					% Fines			Material Description	Max Dry Density	Opt. Moist %	USCS	NM %	LL	PL	Hydraulic Conductivity
			Coarse	Fine	Coarse	Med	Fine	Silt	Clay	Coarse	Med	Fine	Silt	Clay									
WRRTV Site																							
3-O #1	6'-1'	0.0	0.0	0.0	0.5	1.1	48.4	13.3	36.7	Sandy silty clay	110 pcf	18%	CL- ML	8.7	20	13	@6'-2'-6" 8.97E-06 cm/sec	Compaction 93.7% Moisture content 17.6%					
3-O #2	5'-6" -6'	0.0	0.0	0.0	0.0	0.3	13.4	12.2	74.1	Lean clay	106 pcf	20%	CL	9.7	39	14	@5'-7' 4.36E-06 cm/sec	Compaction 100.4% Moisture content 19.9%					
3-Pull #1	6'-1'	0.0	0.0	0.0	0.0	0.5	13.5	20.9	65.1	Lean clay	107 pcf	19%	CL	12.2	36	18	@6'-3'-6" 2.03E-07 cm/sec	Compaction 92.0% Moisture content 18.9%					
3-Pull #2	5'-5'- 6"	0.0	0.0	0.0	0.0	0.1	10.4	20.9	68.6	Lean clay	112 pcf	18%	CL	9.2	34	18	@5'-7' 4.10E-07 cm/sec	Compaction 95.3% Moisture content 17.0%					
3-Q #1	2'-6" -3'	0.0	0.0	0.0	0.0	0.2	9.3	19.8	70.7	Lean clay	114 pcf	16%	CL	11.1	37	17	Not tested						
3-Q #2	7'-6" -8'	0.0	0.0	0.0	0.0	0.3	28.4	18.9	52.4	Lean clay with sand			CL	8.0	28	14	Not tested						

PARTICLE SIZE DISTRIBUTION TEST REPORT



% + 3"		% GRAVEL		% SAND		% FINES	
COARSE	FINE	COARSE	FINE	COARSE	MEDIUM	FINE	CLAY
0.0	0.1	0.1	0.1	1.3	6.6	51.6	40.3

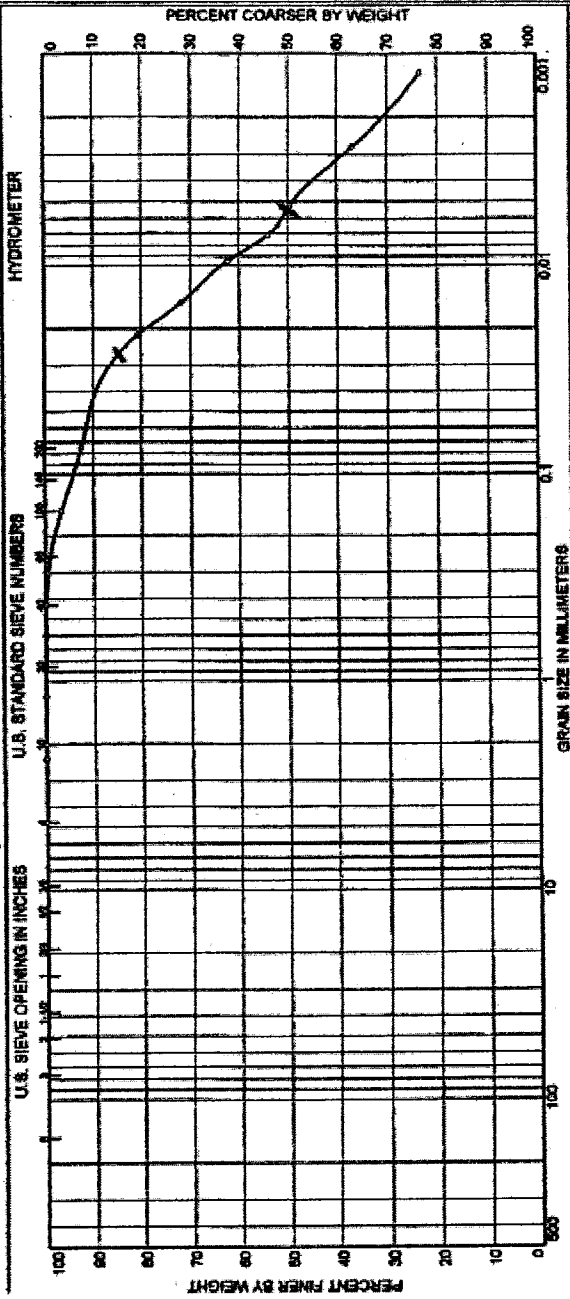
SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	MM %	LL	PL
Riverbed Flats Area	#1-Q	2.0' - 2.5'	5/3/00	CL	Lean clay	10.4%	33	18

Client: Tom Borschel, EBSWI
 Project: INEL CERCLA Disposal Facility (ICDF)
 Project No.: 3XD710130 Plate

INEL MATERIALS LAB

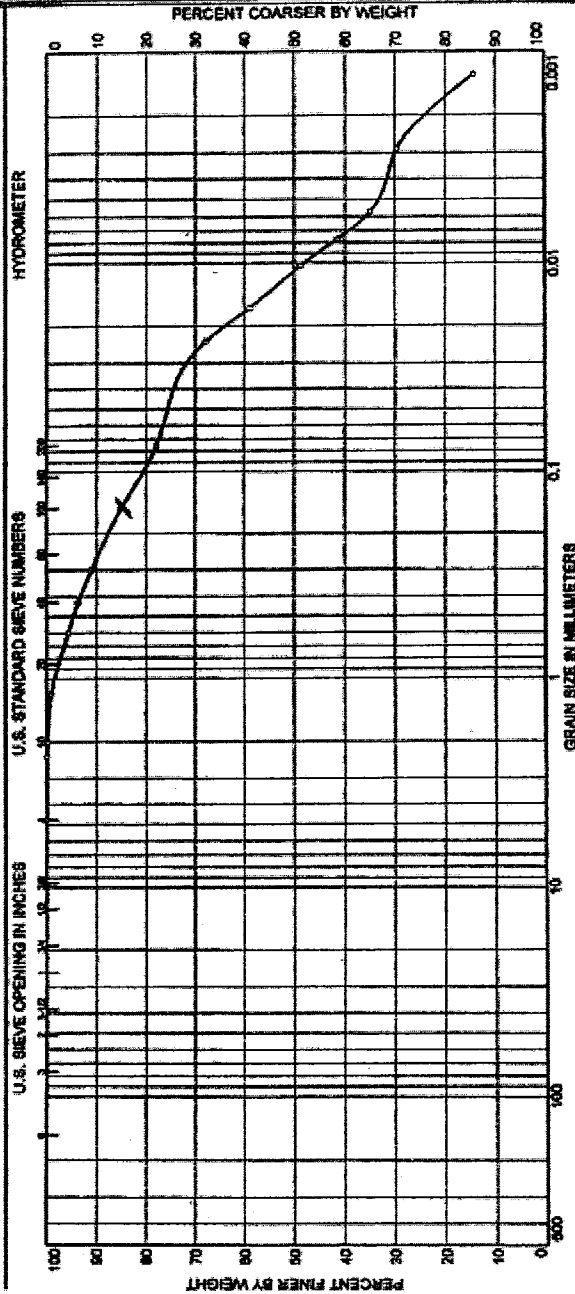
o Sampled from Core #1, core length - 0'-2.5'. Samples collected by others.

PARTICLE SIZE DISTRIBUTION TEST REPORT

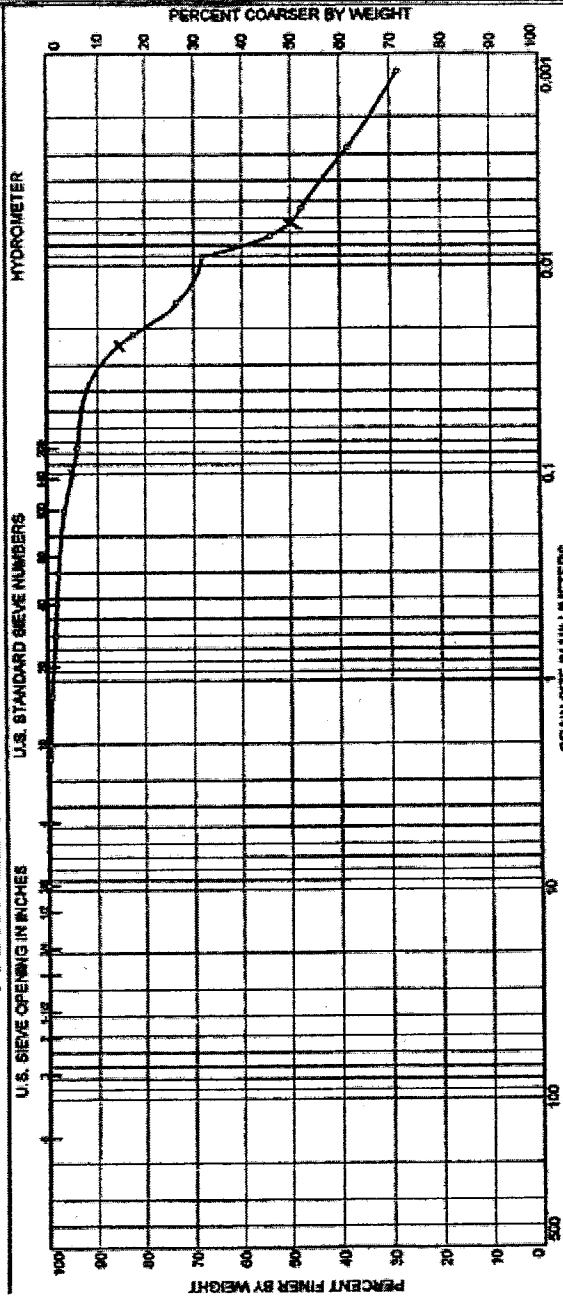


U.S. SIEVE OPENING IN INCHES		U.S. STANDARD SIEVE NUMBERS		HYDROMETER	
100		4		No. 4	
75		20		No. 20	
60		25		No. 25	
42.5		35		No. 35	
30		47.5		No. 47.5	
25		60		No. 60	
20		75		No. 75	
15		100		No. 100	
12.5		125		No. 125	
10		150		No. 150	
7.5		200		No. 200	
6		250		No. 250	
5		30		No. 30	
4.75		40		No. 40	
4.25		45		No. 45	
3.75		50		No. 50	
3.35		55		No. 55	
3.0		60		No. 60	
2.8		65		No. 65	
2.5		70		No. 70	
2.2		75		No. 75	
2.0		80		No. 80	
1.8		85		No. 85	
1.6		90		No. 90	
1.4		95		No. 95	
1.25		100		No. 100	
1.18		105		No. 105	
1.06		110		No. 110	
0.85		125		No. 125	
0.75		150		No. 150	
0.6		200		No. 200	
0.425		35		No. 35	
0.3		47.5		No. 47.5	
0.25		55		No. 55	
0.2		65		No. 65	
0.15		75		No. 75	
0.125		85		No. 85	
0.106		90		No. 90	
0.075		100		No. 100	
0.06		105		No. 105	
0.053		110		No. 110	
0.0475		115		No. 115	
0.0425		120		No. 120	
0.0375		125		No. 125	
0.0335		130		No. 130	
0.03		135		No. 135	
0.028		140		No. 140	
0.025		145		No. 145	
0.022		150		No. 150	
0.02		155		No. 155	
0.018		160		No. 160	
0.016		165		No. 165	
0.015		170		No. 170	
0.014		175		No. 175	
0.0125		180		No. 180	
0.0118		185		No. 185	
0.0106		190		No. 190	
0.009		195		No. 195	
0.008		200		No. 200	
0.0075		205		No. 205	
0.007		210		No. 210	
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0.0058		220		No. 220	
0.0053		225		No. 225	
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0.0044		235		No. 235	
0.004		240		No. 240	
0.0037		245		No. 245	
0.0034		250		No. 250	
0.0031		255		No. 255	
0.0028		260		No. 260	
0.0026		265		No. 265	
0.0024		270		No. 270	
0.0022		275		No. 275	
0.002		280		No. 280	
0.0018		285		No. 285	
0.0016		290		No. 290	
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0.00022		405		No. 405	
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0.00011		445		No. 445	
0.0001		450		No. 450	
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0.00008		460		No. 460	
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0.00007		470		No. 470	
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0.00004		500		No. 500	
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0.000034		510		No. 510	
0.000031		515		No. 515	
0.000028		520		No. 520	
0.000026		525		No. 525	
0.000024		530		No. 530	
0.000022		535		No. 535	
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0.000008		590		No. 590	
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0.0000063		605		No. 605	
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0.00000026		785		No. 785	
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0.00000022		795		No. 795	
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0.00000014		820		No. 820	
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0.00000009		845		No. 845	
0.00000008		850		No. 850	
0.000000075		855		No. 855	
0.00000007		860		No. 860	
0.000000063		865		No. 865	
0.000000058		870		No. 870	
0.000000053		875		No. 875	
0.000000048		880		No. 880	
0.000000044		885		No. 885	
0.00000004		890		No. 890	
0.000000037		895		No. 895	
0.000000034		900		No. 900	
0.000000031		905		No. 905	
0.000000028		910		No. 910	
0.000000026		915		No. 915	
0.000000024		920		No. 920	
0.000000022		925		No. 925	
0.00000002		930		No. 930	
0.000000018		935		No. 935	
0.000000016		940		No. 940	
0.000000015		945		No. 945	
0.000000014		950		No. 950	
0.000000013		955		No. 955	
0.000000012		960		No. 960	
0.000000011		965		No. 965	
0.00000001		970		No. 970	
0.000000009		975		No. 975	
0.000000008		980		No. 980	
0.0000000075		985		No. 985	
0.000000007		990		No. 990	
0.0000000063		995		No. 995	
0.0000000058		1000		No. 1000	
0.0000000053		1005		No. 1005	
0.0000000048		1010		No. 1010	
0.0000000044		1015		No. 1015	
0.000000004		1020		No. 1020	
0.0000000037		1025		No. 1025	
0.0000000034		1030		No. 1030	
0.0000000031		1035		No. 1035	
0.0000000028		1040		No. 1040	
0.0000000026		1045		No. 1045	
0.0000000024		1050		No. 1050	
0.0000000022		1055		No. 1055	
0.000000002		1060		No. 1060	
0.0000000018		1065		No. 1065	
0.0000000016		1070		No. 1070	
0.0000000015					

PARTICLE SIZE DISTRIBUTION TEST REPORT

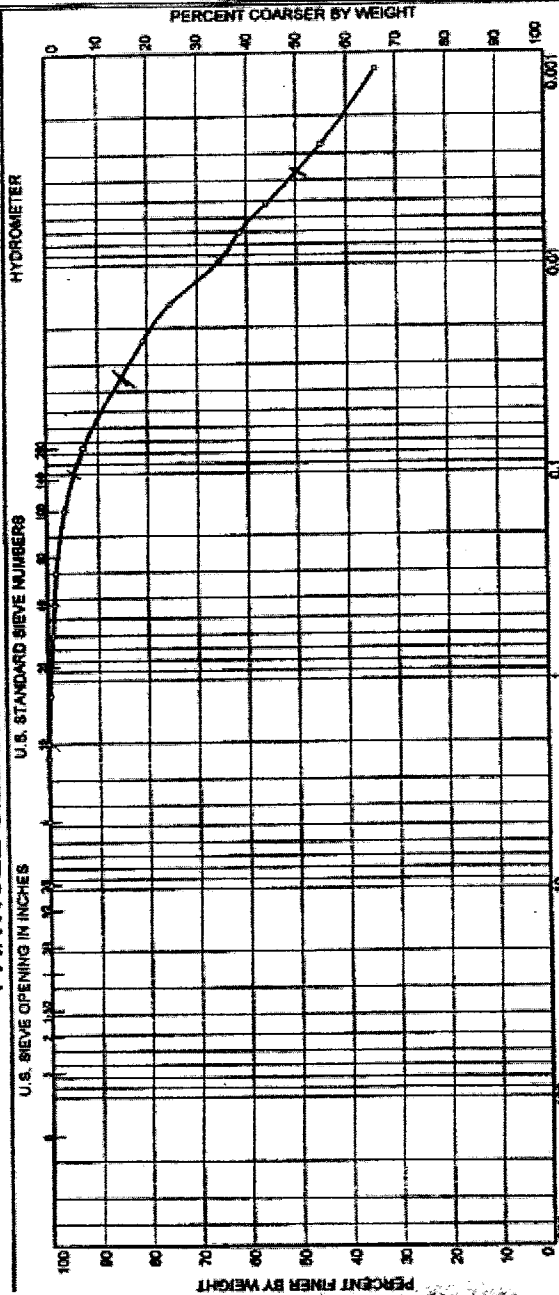


PARTICLE SIZE DISTRIBUTION TEST REPORT



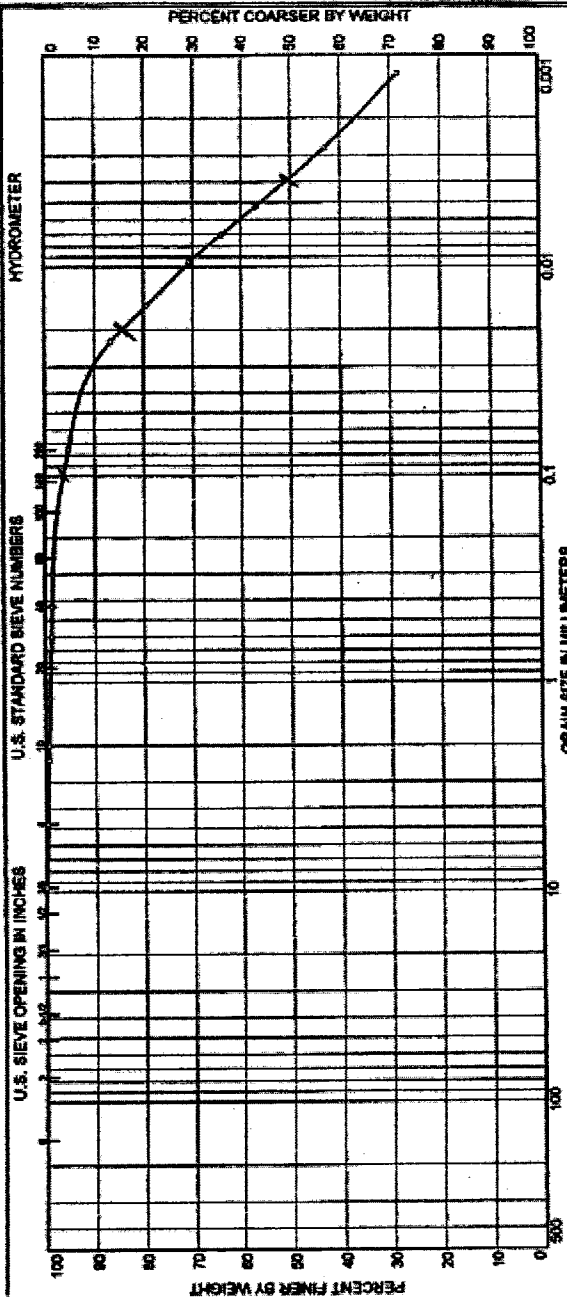
GRAIN SIZE IN MILLIMETERS									
% + 3"		% GRAVEL			% SAND			% FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY	
2	0.0	0.0	0.3	0.2	1.3	4.2	47.3		46.7

PARTICLE SIZE DISTRIBUTION TEST REPORT



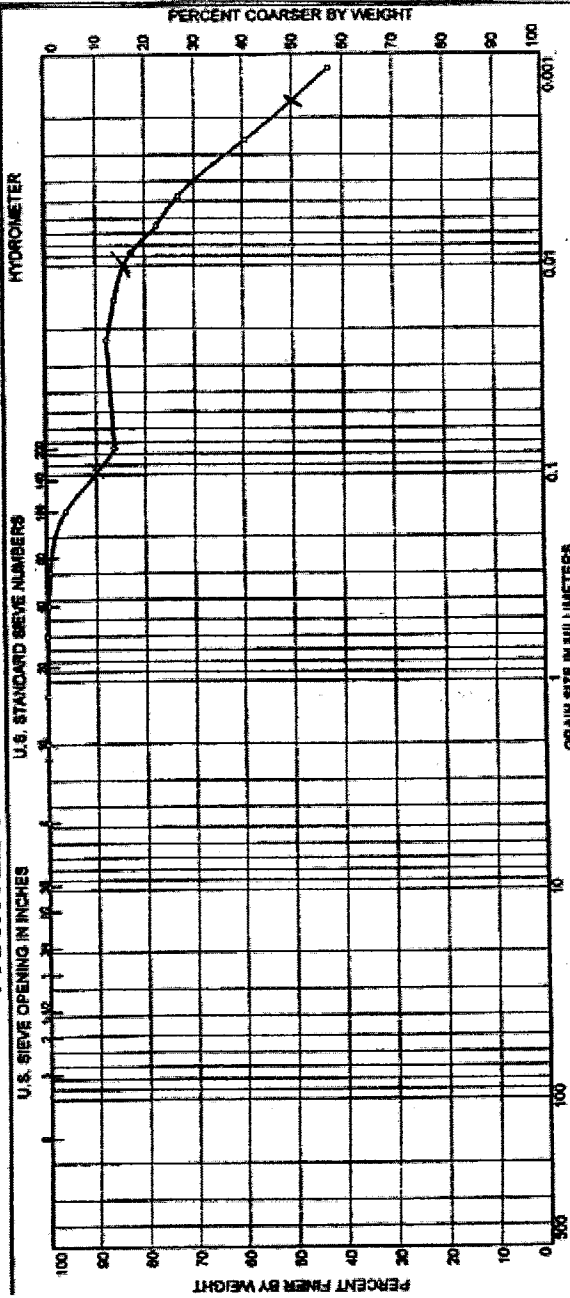
U.S. SIEVE OPENING IN INCHES		U.S. STANDARD SIEVE NUMBERS		HYDROMETER	
100	1.18	10	2.0	20	0.85
60	2.5	60	0.25	40	0.425
40	4.75	40	0.425	20	0.85
20	9.5	20	0.85	10	1.18
10	19.0	10	1.9	5	2.5
5	37.5	5	3.75	2	4.75
2	75.0	2	7.5	1	9.5
1	149.0	1	14.9	0.5	19.0
0.5	298.0	0.5	29.8	0.25	37.5
0.25	596.0	0.25	59.6	0.125	75.0
0.125	1192.0	0.125	119.2	0.0625	149.0
0.0625	2384.0	0.0625	238.4	0.03125	298.0
0.03125	4768.0	0.03125	476.8	0.015625	596.0
0.015625	9536.0	0.015625	953.6	0.0078125	1192.0
0.0078125	19072.0	0.0078125	1907.2	0.00390625	2384.0
0.00390625	38144.0	0.00390625	3814.4	0.001953125	4768.0
0.001953125	76288.0	0.001953125	7628.8	0.0009765625	9536.0
0.0009765625	152576.0	0.0009765625	15257.6	0.00048828125	19072.0
0.00048828125	305152.0	0.00048828125	30515.2	0.000244140625	38144.0
0.000244140625	610304.0	0.000244140625	61030.4	0.0001220703125	76288.0
0.0001220703125	1220608.0	0.0001220703125	122060.8	0.00006103515625	152576.0
0.00006103515625	2441216.0	0.00006103515625	244121.6	0.000030517578125	305152.0
0.000030517578125	4882432.0	0.000030517578125	488243.2	0.0000152587890625	610304.0
0.0000152587890625	9764864.0	0.0000152587890625	976486.4	0.00000762939453125	1220608.0
0.00000762939453125	19529728.0	0.00000762939453125	1952972.8	0.000003814697265625	2441216.0
0.000003814697265625	39059456.0	0.000003814697265625	3905945.6	0.0000019073486328125	4882432.0
0.0000019073486328125	78118912.0	0.0000019073486328125	7811891.2	0.00000095367431640625	9764864.0
0.00000095367431640625	156237824.0	0.00000095367431640625	15623782.4	0.000000476837158203125	19529728.0
0.000000476837158203125	312475648.0	0.000000476837158203125	31247564.8	0.0000002384185791015625	39059456.0
0.0000002384185791015625	624951296.0	0.0000002384185791015625	62495129.6	0.00000011920928955078125	78118912.0
0.00000011920928955078125	1249902592.0	0.00000011920928955078125	124990259.2	0.000000059604644775390625	156237824.0
0.000000059604644775390625	2499805184.0	0.000000059604644775390625	249980518.4	0.0000000298023223876953125	312475648.0
0.0000000298023223876953125	4999610368.0	0.0000000298023223876953125	499961036.8	0.00000001490116119384765625	624951296.0
0.00000001490116119384765625	9999220736.0	0.00000001490116119384765625	999922073.6	0.000000007450580596923828125	1249902592.0
0.000000007450580596923828125	19998441472.0	0.000000007450580596923828125	1999844147.2	0.0000000037252902984619140625	2499805184.0
0.0000000037252902984619140625	39996882944.0	0.0000000037252902984619140625	3999688294.4	0.00000000186264514923095703125	4999610368.0
0.00000000186264514923095703125	79993765888.0	0.00000000186264514923095703125	7999376588.8	0.000000000931322574615478515625	9999220736.0
0.000000000931322574615478515625	159987531776.0	0.000000000931322574615478515625	15998753177.6	0.0000000004656612873077392578125	19998441472.0
0.0000000004656612873077392578125	319975063552.0	0.0000000004656612873077392578125	31997506355.2	0.00000000023283064365386962890625	39996882944.0
0.00000000023283064365386962890625	639950127104.0	0.00000000023283064365386962890625	63995012710.4	0.000000000116415321826934814453125	79993765888.0
0.000000000116415321826934814453125	1279900254208.0	0.000000000116415321826934814453125	127990025420.8	0.0000000000582076609134674072265625	159987531776.0
0.0000000000582076609134674072265625	2559800508416.0	0.0000000000582076609134674072265625	255980050841.6	0.00000000002910383045673370361328125	319975063552.0
0.00000000002910383045673370361328125	5119601016832.0	0.00000000002910383045673370361328125	511960101683.2	0.000000000014551915228366851806640625	639950127104.0
0.000000000014551915228366851806640625	10239202033664.0	0.000000000014551915228366851806640625	1023920203366.4	0.0000000000072759576141834259033203125	1279900254208.0
0.0000000000072759576141834259033203125	20478404067328.0	0.0000000000072759576141834259033203125	2047840406732.8	0.00000000000363797880709171295166015625	2559800508416.0
0.00000000000363797880709171295166015625	40956808134656.0	0.00000000000363797880709171295166015625	4095680813465.6	0.000000000001818989403545856475830078125	5119601016832.0
0.000000000001818989403545856475830078125	81913616269312.0	0.000000000001818989403545856475830078125	8191361626931.2	0.0000000000009094947017729282379150390625	10239202033664.0
0.0000000000009094947017729282379150390625	163827232538624.0	0.0000000000009094947017729282379150390625	16382723253862.4	0.00000000000045474735088646411895751953125	16382723253862.4
0.00000000000045474735088646411895751953125	327654465077248.0	0.00000000000045474735088646411895751953125	32765446507724.8	0.000000000000227373675443232059478759765625	32765446507724.8
0.000000000000227373675443232059478759765625	655308930154496.0	0.000000000000227373675443232059478759765625	65530893015449.6	0.0000000000001136868377216160297393798828125	65530893015449.6
0.0000000000001136868377216160297393798828125	1310617860308992.0	0.0000000000001136868377216160297393798828125	131061786030899.2	0.00000000000005684341886080801486968994140625	131061786030899.2
0.00000000000005684341886080801486968994140625	2621235720617984.0	0.00000000000005684341886080801486968994140625	262123572061798.4	0.000000000000028421709430404007434844970703125	262123572061798.4
0.000000000000028421709430404007434844970703125	5242471441235968.0	0.000000000000028421709430404007434844970703125	524247144123596.8	0.0000000000000142108547152020037174224853515625	524247144123596.8
0.0000000000000142108547152020037174224853515625	10484942882471936.0	0.0000000000000142108547152020037174224853515625	1048494288247193.6	0.00000000000000710542735760100185871124267578125	1048494288247193.6
0.00000000000000710542735760100185871124267578125	20969885764943872.0	0.00000000000000710542735760100185871124267578125	2096988576494387.2	0.000000000000003552713678800500929355621337890625	2096988576494387.2
0.000000000000003552713678800500929355621337890625	41939771529887744.0	0.000000000000003552713678800500929355621337890625	4193977152988774.4	0.0000000000000017763568394002504646778106689453125	4193977152988774.4
0.0000000000000017763568394002504646778106689453125	83879543059775488.0	0.0000000000000017763568394002504646778106689453125	8387954305977548.8	0.00000000000000088817841970012523233890533447265625	8387954305977548.8
0.00000000000000088817841970012523233890533447265625	167759086119550976.0	0.00000000000000088817841970012523233890533447265625	16775908611955097.6	0.000000000000000444089209850062616169452667236328125	16775908611955097.6
0.000000000000000444089209850062616169452667236328125	335518172239101952.0	0.000000000000000444089209850062616169452667236328125	33551817223910195.2	0.0000000000000002220446049250313080847263336181640625	33551817223910195.2
0.0000000000000002220446049250313080847263336181640625	671036344478203904.0	0.0000000000000002220446049250313080847263336181640625	67103634447820390.4	0.00000000000000011102230246251565404236316680908203125	67103634447820390.4
0.00000000000000011102230246251565404236316680908203125	1342072688956407808.0	0.00000000000000011102230246251565404236316680908203125	134207268895640780.8	0.00000000000000005551115123125782702118158334044015625	134207268895640780.8
0.00000000000000005551115123125782702118158334044015625	2684145377912815616.0	0.00000000000000005551115123125782702118158334044015625	268414537791281561.6	0.00000000000000002775557561562891351059079167022015625	268414537791281561.6
0.00000000000000002775557561562891351059079167022015625	5368290755825631232.0	0.00000000000000002775557561562891351059079167022015625	536829075582563123.2	0.00000000000000001387778780781445675529539583511015625	536829075582563123.2
0.00000000000000001387778780781445675529539583511015625	10736581511651262464.0	0.00000000000000001387778780781445675529539583511015625	1073658151165126246.4	0.000000000000000006938893903907228377647697917555078125	1073658151165126246.4
0.000000000000000006938893903907228377647697917555078125	21473163023302524928.0	0.000000000000000006938893903907228377647697917555078125	2147316302330252492.8	0.00000000000000000346944695195361418882384895877775078125	2147316302330252492.8
0.00000000000000000346944695195361418882384895877775078125	42946326046605049856.0	0.00000000000000000346944695195361418882384895877775078125	4294632604660504985.6	0.000000000000000001734723475976807094411924479388875078125	4294632604660504985.6
0.000000000000000001734723475976807094411924479388875078125	85892652093210099712.0	0.000000000000000001734723475976807094411924479388875078125	8589265209321009971.2	0.0000000000000000008673617379884035472205962396944375078125	8589265209321009971.2
0.0000000000000000008673617379884035472205962396944375078125	171785304186420199424.0	0.0000000000000000008673617379884035472205962396944375078125	17178530418642019942.4	0.00000000000000000043368086899420177361029811984721875078125	17178530418642019942.4
0.00000000000000000043368086899420177361029811984721875078125	343570608372840398848.0	0.00000000000000000043368086899420177361029811984721875078125	34357060837284039884.8	0.00000000000000000021684043449710088680514905992361015625	34357060837284039884.8
0.00000000000000000021684043449710088680514905992361015625	687141216745680797696.0	0.00000000000000000021684043449710088680514905992361015625	68714121674568079769.6	0.000000000000000000108420217248550443402	

PARTICLE SIZE DISTRIBUTION TEST REPORT



U.S. SIEVE OPENING IN INCHES		U.S. STANDARD SIEVE NUMBERS		HYDROMETER	
1/2	10	20	75	0.075	200
3/4	16	30	100	0.15	425
1	25	40	150	0.3	600
1 1/4	35	50	200	0.425	700
1 1/2	40	60	250	0.6	800
1 3/4	45	70	300	0.85	900
2	50	80	350	1.18	1000
2 1/4	55	90	400	1.49	1100
2 1/2	60	100	450	1.75	1200
2 3/4	65	110	500	2.0	1300
3	70	120	550	2.5	1400
3 1/4	75	130	600	3.0	1500
3 1/2	80	140	650	3.55	1600
3 3/4	85	150	700	4.75	1700
4	90	160	750	5.9	1800
4 1/4	95	170	800	7.0	1900
4 1/2	100	180	850	8.0	2000
4 3/4	100	190	900	9.5	2100
5	100	200	950	10.6	2200
5 1/4	100	210	1000	11.8	2300
5 1/2	100	220	1050	13.0	2400
5 3/4	100	230	1100	14.3	2500
6	100	240	1150	15.7	2600
6 1/4	100	250	1200	17.0	2700
6 1/2	100	260	1250	18.5	2800
6 3/4	100	270	1300	20.0	2900
7	100	280	1350	21.5	3000
7 1/4	100	290	1400	23.0	3100
7 1/2	100	300	1450	24.5	3200
7 3/4	100	310	1500	26.0	3300
8	100	320	1550	27.5	3400
8 1/4	100	330	1600	29.0	3500
8 1/2	100	340	1650	30.5	3600
8 3/4	100	350	1700	32.0	3700
9	100	360	1750	33.5	3800
9 1/4	100	370	1800	35.0	3900
9 1/2	100	380	1850	36.5	4000
9 3/4	100	390	1900	38.0	4100
10	100	400	1950	39.5	4200
10 1/4	100	410	2000	41.0	4300
10 1/2	100	420	2050	42.5	4400
10 3/4	100	430	2100	44.0	4500
11	100	440	2150	45.5	4600
11 1/4	100	450	2200	47.0	4700
11 1/2	100	460	2250	48.5	4800
11 3/4	100	470	2300	50.0	4900
12	100	480	2350	51.5	5000
12 1/4	100	490	2400	53.0	5100
12 1/2	100	500	2450	54.5	5200
12 3/4	100	510	2500	56.0	5300
13	100	520	2550	57.5	5400
13 1/4	100	530	2600	59.0	5500
13 1/2	100	540	2650	60.5	5600
13 3/4	100	550	2700	62.0	5700
14	100	560	2750	63.5	5800
14 1/4	100	570	2800	65.0	5900
14 1/2	100	580	2850	66.5	6000
14 3/4	100	590	2900	68.0	6100
15	100	600	2950	69.5	6200
15 1/4	100	610	3000	71.0	6300
15 1/2	100	620	3050	72.5	6400
15 3/4	100	630	3100	74.0	6500
16	100	640	3150	75.5	6600
16 1/4	100	650	3200	77.0	6700
16 1/2	100	660	3250	78.5	6800
16 3/4	100	670	3300	80.0	6900
17	100	680	3350	81.5	7000
17 1/4	100	690	3400	83.0	7100
17 1/2	100	700	3450	84.5	7200
17 3/4	100	710	3500	86.0	7300
18	100	720	3550	87.5	7400
18 1/4	100	730	3600	89.0	7500
18 1/2	100	740	3650	90.5	7600
18 3/4	100	750	3700	92.0	7700
19	100	760	3750	93.5	7800
19 1/4	100	770	3800	95.0	7900
19 1/2	100	780	3850	96.5	8000
19 3/4	100	790	3900	98.0	8100
20	100	800	3950	99.5	8200
20 1/4	100	810	4000	100.0	8300
20 1/2	100	820	4050	100.0	8400
20 3/4	100	830	4100	100.0	8500
21	100	840	4150	100.0	8600
21 1/4	100	850	4200	100.0	8700
21 1/2	100	860	4250	100.0	8800
21 3/4	100	870	4300	100.0	8900
22	100	880	4350	100.0	9000
22 1/4	100	890	4400	100.0	9100
22 1/2	100	900	4450	100.0	9200
22 3/4	100	910	4500	100.0	9300
23	100	920	4550	100.0	9400
23 1/4	100	930	4600	100.0	9500
23 1/2	100	940	4650	100.0	9600
23 3/4	100	950	4700	100.0	9700
24	100	960	4750	100.0	9800
24 1/4	100	970	4800	100.0	9900
24 1/2	100	980	4850	100.0	10000
24 3/4	100	990	4900	100.0	10100
25	100	1000	4950	100.0	10200
25 1/4	100	1010	5000	100.0	10300
25 1/2	100	1020	5050	100.0	10400
25 3/4	100	1030	5100	100.0	10500
26	100	1040	5150	100.0	10600
26 1/4	100	1050	5200	100.0	10700
26 1/2	100	1060	5250	100.0	10800
26 3/4	100	1070	5300	100.0	10900
27	100	1080	5350	100.0	11000
27 1/4	100	1090	5400	100.0	11100
27 1/2	100	1100	5450	100.0	11200
27 3/4	100	1110	5500	100.0	11300
28	100	1120	5550	100.0	11400
28 1/4	100	1130	5600	100.0	11500
28 1/2	100	1140	5650	100.0	11600
28 3/4	100	1150	5700	100.0	11700
29	100	1160	5750	100.0	11800
29 1/4	100	1170	5800	100.0	11900
29 1/2	100	1180	5850	100.0	12000
29 3/4	100	1190	5900	100.0	12100
30	100	1200	5950	100.0	12200
30 1/4	100	1210	6000	100.0	12300
30 1/2	100	1220	6050	100.0	12400
30 3/4	100	1230	6100	100.0	12500
31	100	1240	6150	100.0	12600
31 1/4	100	1250	6200	100.0	12700
31 1/2	100	1260	6250	100.0	12800
31 3/4	100	1270	6300	100.0	12900
32	100	1280	6350	100.0	13000
32 1/4	100	1290	6400	100.0	13100
32 1/2	100	1300	6450	100.0	13200
32 3/4	100	1310	6500	100.0	13300
33	100	1320	6550	100.0	13400
33 1/4	100	1330	6600	100.0	13500
33 1/2	100	1340	6650	100.0	13600
33 3/4	100	1350	6700	100.0	13700
34	100	1360	6750	100.0	13800
34 1/4	100	1370	6800	100.0	13900
34 1/2	100	1380	6850	100.0	14000
34 3/4	100	1390	6900	100.0	14100
35	100	1400	6950	100.0	14200
35 1/4	100	1410	7000	100.0	14300
35 1/2	100	1420	7050	100.0	14400
35 3/4	100	1430	7100	100.0	14500
36	100	1440	7150	100.0	14600
36 1/4	100	1450	7200	100.0	14700
36 1/2	100	1460	7250	100.0	14800
36 3/4	100	1470	7300	100.0	14900
37	100	1480	7350	100.0	15000
37 1/4	100	1490	7400	100.0	15100
37 1/2	100	1500	7450	100.0	15200
37 3/4	100	1510	7500	100.0	15300
38	100	1520	7550	100.0	15400
38 1/4	100	1530	7600	100.0	15500
38 1/2	100	1540	7650	100.0	15600
38 3/4	100	1550	7700	100.0	15700
39	100	1560	7750	100.0	15800
39 1/4	100	1570	7800	100.0	15900
39 1/2	100	1580	7850	100.0	16000
39 3/4	100	1590	7900	100.0	16100
40	100	1600	7950	100.0	16200
40 1/4	100	1610	8000	100.0	16300
40 1/2	100	1620	8050	100.0	16400
40 3/4	100	1630	8100	100.0	16500
41	100	1640	8150	100.0	16600
41 1/4	100	1650	8200	100.0	16700
41 1/2	100	1660	8250	100.0	16800
41 3/4	100	1670	8300	100.0	16900
42	100	1680	8350	100.0	17000
42 1/4	100	1690	8400	100.0	17100
42 1/2	100	1700	8450	100.0	17200
42 3/4	100	1710	8500	100.0	17300
43	100	1720	8550	100.0	17400
43 1/4					

PARTICLE SIZE DISTRIBUTION TEST REPORT



GRADUITY SCALE ON MATERIALS LAB									
% + 3"		% GRAVEL		% SAND			% FINES		
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY	
2	0.0	0.0	0.0	0.0	0.3	13.4	12.2	74.1	

PERCENT FINER BY WEIGHT

U.S. STANDARD SIEVE NUMBERS

U.S. SIEVE OPENING IN INCHES

PERCENT COARSER BY WEIGHT

HYDROMETER

Sieve Opening (inches)	Sieve Number	Percent Finer (%)
0.075	No. 200	100
0.075	No. 200	5
0.075	No. 200	0

GRAIN SIZE IN MILLIMETERS									
% + 3"	% GRAVEL			% SAND			% FINE		
	COARSE	FINE		COARSE	MEDIUM		FW	44.7	CLAY
0.0	0.0	0.0		0.0	0.5		13.5	20.9	65.1

MATERIAL DESCRIPTION									
SOURCE	SAMPLE #	DEPTH/LEV.	DATE SAMPLED	USCS					
WRRTP AREA	#3-PAIL	0.5' - 1.0'	6-14-00	CL	LEAD clay				
	#1								

				MM %	LL	PL
				12.2%	36	18

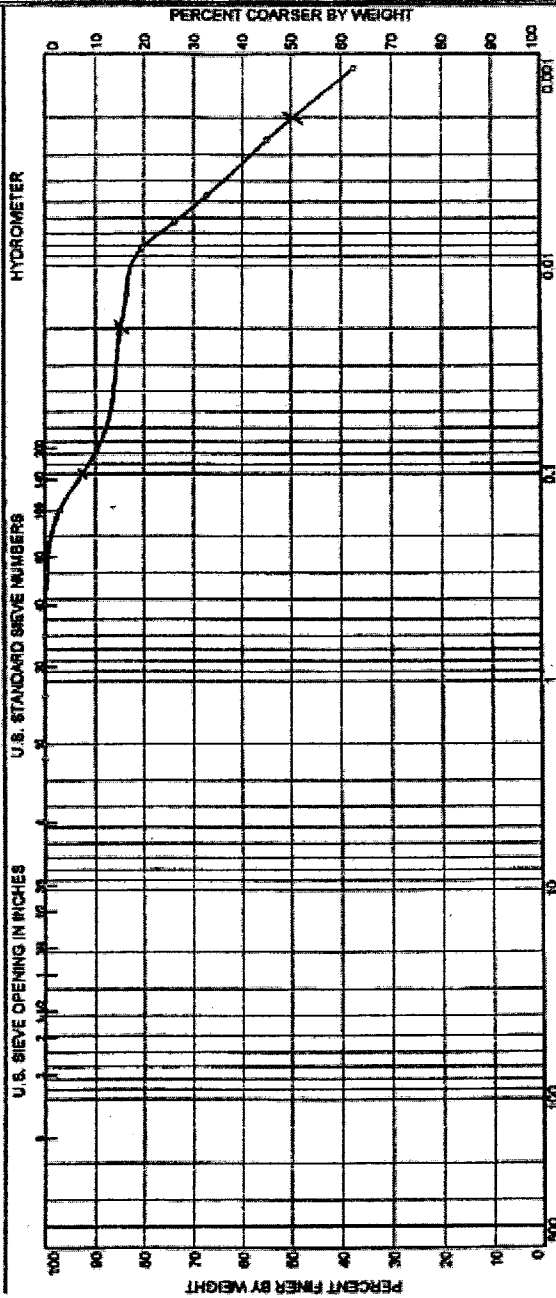
☐ Sampled from WRRTP core #1, Borehole #3-P Alt., core length 0.0'-2.5'. Sampled by others.

Client: Ton Boraschel BEWI

Project: INEL CERCLA Decont Facility (RCDF)

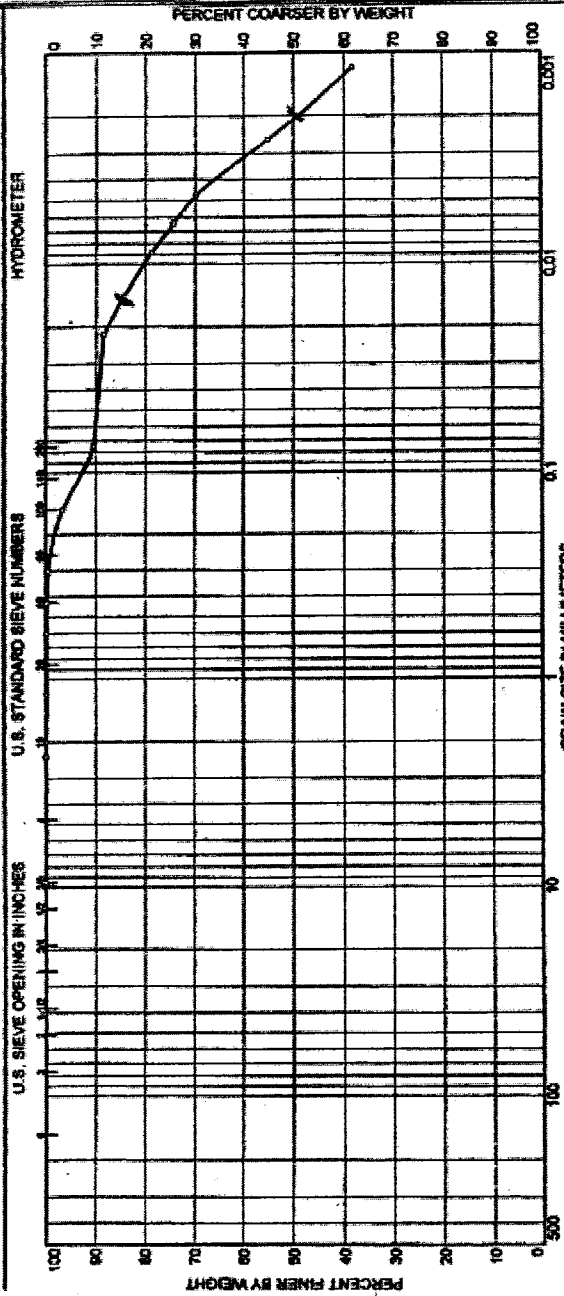
INEL MATERIALS LAB

PARTICLE SIZE DISTRIBUTION TEST REPORT



U.S. SIEVE OPENING IN INCHES		U.S. STANDARD SIEVE NUMBERS		HYDROMETER	
GRAIN SIZE IN MILLIMETERS					
% + 2"	% GRAVEL	% SAND	% FINES		
0.0	COARSE 0.0 FINE 0.0	COARSE 0.0 MEDIUM 0.1 FINE 10.4	BILT 20.9 CLAY 68.6		
SOURCE WRRTP Area #3		DATE SAMPLED 6-14-00		MATERIAL DESCRIPTION Lablight	
SAMPLE # 83-P All		DEPTH/LEV. 5.0' - 5.5'		UICB CL	
Client Tom Borshel BBWI		Project INEL CERCLA Disposal Facility (OCDF)		INEL MATERIALS LAB	
Project No. 3X0710130		Plate		<p>Sampled from WRRTP, core #3, Borehole 83-P All</p> <p>Sampled by others.</p>	

PARTICLE SIZE DISTRIBUTION TEST REPORT

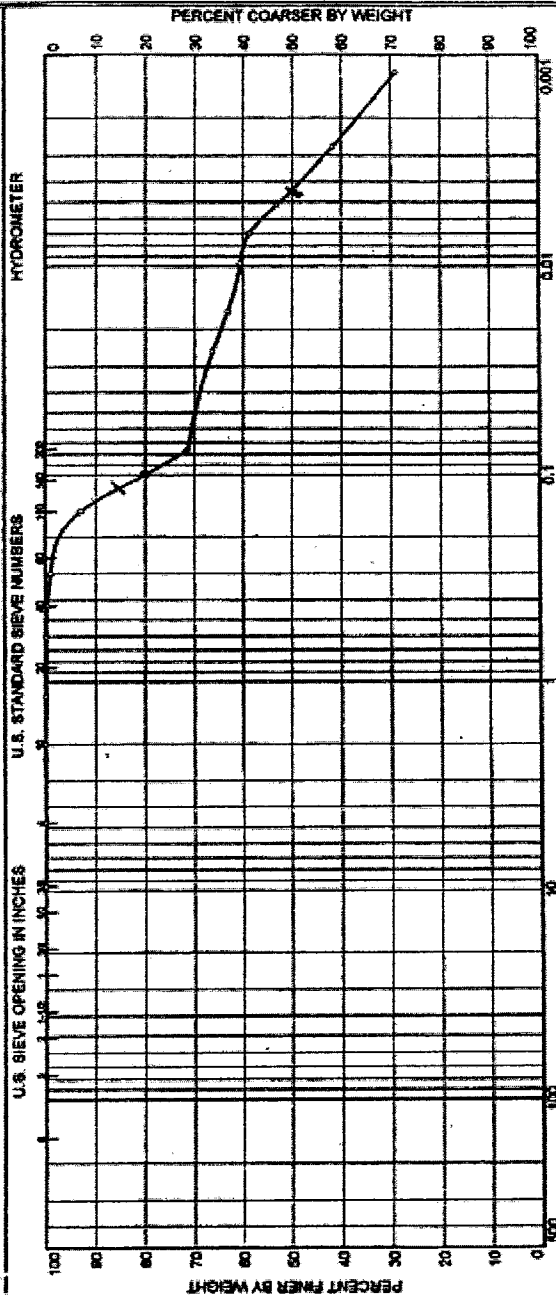


U.S. Sieve Opening in Inches		U.S. Standard Sieve Numbers		Grain Size in Millimeters		Percent Coarser by Weight	
10	2	10	20	10	20	10	20
15	3	30	40	5	10	5	10
20	4	40	60	4	7.5	4	7.5
25	5	60	80	3	6	3	6
30	6	80	100	2.5	5	2.5	5
35	7	100		2	4.75	2	4.75
40	8			1.75	4	1.75	4
45	9			1.5	3.75	1.5	3.75
50	10			1.25	3.35	1.25	3.35
55	11			1.18	3.18	1.18	3.18
60	12			1.06	2.95	1.06	2.95
65	13			0.95	2.75	0.95	2.75
70	14			0.85	2.5	0.85	2.5
75	15			0.75	2.25	0.75	2.25
80	16			0.675	2.0	0.675	2.0
85	17			0.6	1.75	0.6	1.75
90	18			0.53	1.5	0.53	1.5
95	19			0.475	1.25	0.475	1.25
100	20			0.425	1.06	0.425	1.06
105	21			0.375	0.95	0.375	0.95
110	22			0.335	0.85	0.335	0.85
115	23			0.3	0.75	0.3	0.75
120	24			0.275	0.675	0.275	0.675
125	25			0.25	0.6	0.25	0.6
130	26			0.225	0.53	0.225	0.53
135	27			0.2	0.475	0.2	0.475
140	28			0.18	0.425	0.18	0.425
145	29			0.16	0.375	0.16	0.375
150	30			0.15	0.335	0.15	0.335
155	31			0.138	0.3	0.138	0.3
160	32			0.125	0.275	0.125	0.275
165	33			0.118	0.25	0.118	0.25
170	34			0.106	0.225	0.106	0.225
175	35			0.095	0.2	0.095	0.2
180	36			0.085	0.18	0.085	0.18
185	37			0.075	0.16	0.075	0.16
190	38			0.075	0.15	0.075	0.15
195	39			0.075	0.14	0.075	0.14
200	40			0.075	0.13	0.075	0.13
205	41			0.075	0.12	0.075	0.12
210	42			0.075	0.11	0.075	0.11
215	43			0.075	0.1	0.075	0.1
220	44			0.075	0.09	0.075	0.09
225	45			0.075	0.08	0.075	0.08
230	46			0.075	0.075	0.075	0.075
235	47			0.075	0.07	0.075	0.07
240	48			0.075	0.065	0.075	0.065
245	49			0.075	0.06	0.075	0.06
250	50			0.075	0.055	0.075	0.055
255	51			0.075	0.05	0.075	0.05
260	52			0.075	0.045	0.075	0.045
265	53			0.075	0.04	0.075	0.04
270	54			0.075	0.035	0.075	0.035
275	55			0.075	0.03	0.075	0.03
280	56			0.075	0.025	0.075	0.025
285	57			0.075	0.02	0.075	0.02
290	58			0.075	0.018	0.075	0.018
295	59			0.075	0.016	0.075	0.016
300	60			0.075	0.015	0.075	0.015
305	61			0.075	0.014	0.075	0.014
310	62			0.075	0.013	0.075	0.013
315	63			0.075	0.012	0.075	0.012
320	64			0.075	0.011	0.075	0.011
325	65			0.075	0.01	0.075	0.01
330	66			0.075	0.009	0.075	0.009
335	67			0.075	0.008	0.075	0.008
340	68			0.075	0.007	0.075	0.007
345	69			0.075	0.006	0.075	0.006
350	70			0.075	0.005	0.075	0.005
355	71			0.075	0.004	0.075	0.004
360	72			0.075	0.003	0.075	0.003
365	73			0.075	0.002	0.075	0.002
370	74			0.075	0.001	0.075	0.001
375	75			0.075	0.000	0.075	0.000
380	76			0.075	0.000	0.075	0.000
385	77			0.075	0.000	0.075	0.000
390	78			0.075	0.000	0.075	0.000
395	79			0.075	0.000	0.075	0.000
400	80			0.075	0.000	0.075	0.000
405	81			0.075	0.000	0.075	0.000
410	82			0.075	0.000	0.075	0.000
415	83			0.075	0.000	0.075	0.000
420	84			0.075	0.000	0.075	0.000
425	85			0.075	0.000	0.075	0.000
430	86			0.075	0.000	0.075	0.000
435	87			0.075	0.000	0.075	0.000
440	88			0.075	0.000	0.075	0.000
445	89			0.075	0.000	0.075	0.000
450	90			0.075	0.000	0.075	0.000
455	91			0.075	0.000	0.075	0.000
460	92			0.075	0.000	0.075	0.000
465	93			0.075	0.000	0.075	0.000
470	94			0.075	0.000	0.075	0.000
475	95			0.075	0.000	0.075	0.000
480	96			0.075	0.000	0.075	0.000
485	97			0.075	0.000	0.075	0.000
490	98			0.075	0.000	0.075	0.000
495	99			0.075	0.000	0.075	0.000
500	100			0.075	0.000	0.075	0.000

INEL MATERIALS LAB

Client: Terra Borealis BHW
Project: INEL CERCLA Disposal Facility (ICDF)
Project No. 3XD710130 Plate

PARTICLE SIZE DISTRIBUTION TEST REPORT



% GRAVEL		% SAND		% FINES	
COARSE	FINE	COARSE	FINE	CLAY	LL
0.0	0.0	0.0	28.4	18.9	52.4
SOURCE		DATE SAMPLED		MATERIAL DESCRIPTION	
WRRTF Area		6-19-00		Lean clay with sand	
SAMPLE #		LUGS		MM %	
#3-Q #2		CL		8.0%	
DISTANCE		DATE SAMPLED		LL	
7.5' - 9.0'		6-19-00		28	
Client: Tom Barschel, BSWI		Project: INEL CERCLA Decont Facility (ICDF)		PL	
Project: INEL CERCLA Decont Facility (ICDF)		Project No. 3XD710130		Plate	

Sampled from WRRTF, core #4, borehole #3-Q, core length 7.5' to 9.0'. Sampled by others.

INEL MATERIALS LAB

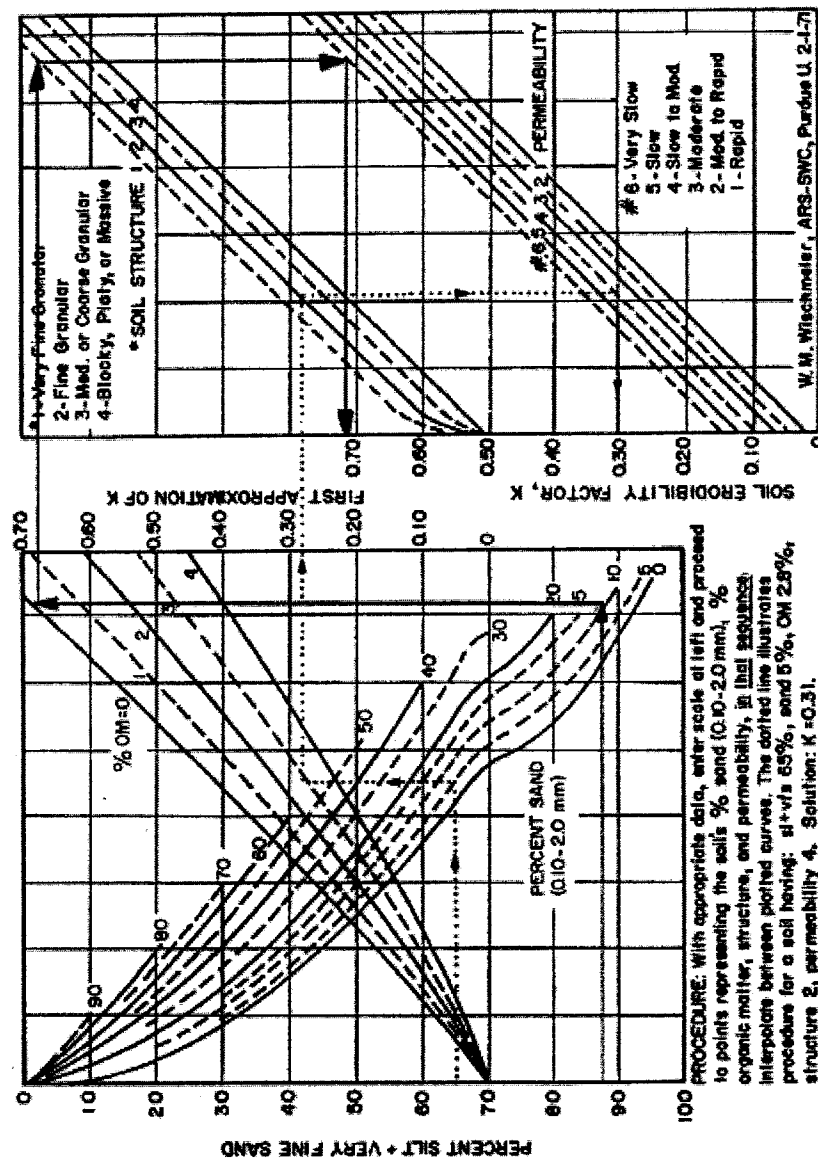
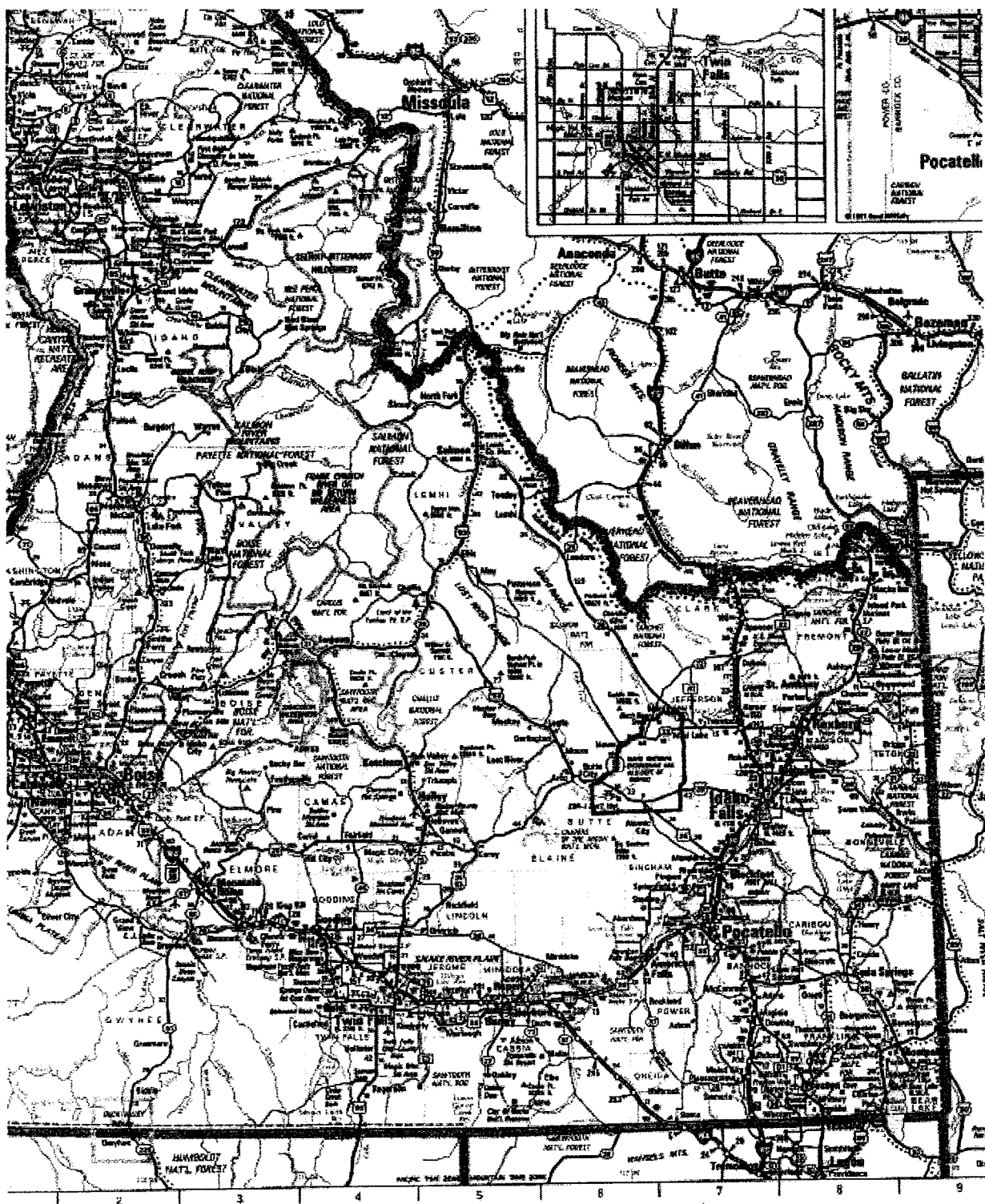


Fig. 5.1. Nomograph for determining soil erodibility factor K. Source: after Wischmeier et al., 1971.



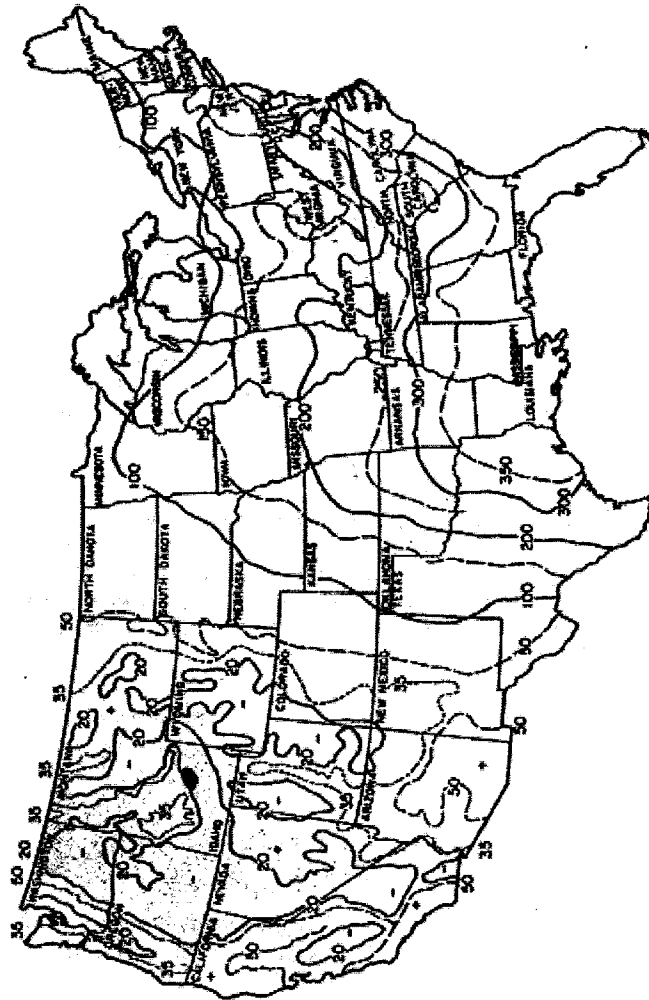


Figure 5.3. Average annual values of the rainfall-erosivity factor, R. (Stewart et al., 1975)

5.1.2.3 The Topographic Factor (LS)

Although the effects of both length and steepness of slope have been investigated separately in different research efforts, it is more convenient for analytical purposes to combine the two into one topographic factor, LS. Wischmeier and Smith (1978) developed plots correlating the topographic factor for slopes up to 500 meters in length at slope inclinations from 0.5% up to 50%. Note that flat, short slopes will have less erosion than long, steep slopes and it is to the benefit of the design engineer to optimize slope length and gradients to fit the topography.

The equation to determine the LS factor is as follows:

$$LS = \frac{650 + 450s + 65s^2}{10,000 + s^2} \frac{L}{72.6}^m \quad (5.2)$$

where LS = topographic factor
L = slope length in feet
s = slope steepness in percent
m = exponent dependent upon slope steepness

The slope dependent exponent m is presented in Table 5.2.

Table 5.2 Slope Dependent Exponent

Slope (percent)	m
$s < 1.0$	0.2
$1.0 < s < 3.0$	0.3
$3.0 < s < 5.0$	0.4
$5.0 < s < 10.0$	0.5
$s > 10.0$	0.6

5.1.2.4 The VM Factor

The VM factor is the erosion control factor applied in place of the cover and erosion control factors found in the USLE. The erosion control factor accounts for measures implemented at the construction site to include vegetation, mulching, chemical treatments and sprayed emulsions to impede or reduce erosion due to the overland flow of water. Values of the VM factor relative to site-specific conditions are presented in Table 5.3.

The VM factor is perhaps the most sensitive factor to effect the computed erosion loss for a given site. As shown by the values presented

on Table 5.3, the development of a permanent vegetative cover can have a significant impact in reducing the computed erosion loss. However, the effectiveness of a vegetative cover over long-term periods should be questioned unless other protective schemes, such as armoring of the cover with the proper size material, are also included in the design.

5.1.2.5 Example Problem

An example problem in how to use the MUSLE is provided below.

Assumptions:

Site location:	Western Colorado
Site description:	Uncovered tailings pond
Pond size:	160 acres
Slope:	3%
Length:	2500 ft
Material:	42% sand greater than 0.10 mm; 58% fine sand and silt less than 0.10 mm; 5% clay less than 0.002 mm; 0% organics; (53% silt plus fine sand less than 0.1 mm); Consistency - fine granular; Permeability - slow to moderate.

The following factors have been determined for use in Equation 5.1.

$R = 20$ from Table 5.1

$K = 0.50$ from Figure 5.1

$LS = 0.747$ from Equation 5.2 and Table 5.2

$VM = 1.0$ (average from Table 5.3 based on an undisturbed surface)

Using Equation 5.1, the annual soil loss (A) from the tailings pond due to sheet erosion caused by flowing water is computed to be 7.47 tons/acre/year, or 1195 tons/year from the facility. Therefore, the cover is estimated to erode at a rate of 0.003 ft per year, or 0.3 ft/century.

5.2 SUMMARY AND FUTURE STUDIES

The main application of the soil loss equation approach in the evaluation of cover integrity is to determine whether it is possible for sheet erosion to penetrate the tailings cover, thereby exposing bare tailings and constituting a failure of the cover. The followup study will concentrate

Table S.3. Typical VM Factor Values Reported in the Literature.^a

Condition	VM Factor
1. Bare soil conditions	
freshly disked to 6-8 inches	1.00
after one rain	0.89
loose to 12 inches smooth	0.90
loose to 12 inches rough	0.80
compacted bulldozer scraped up and down	1.30
same except root raked	1.20
compacted bulldozer scraped across slope	1.20
same except root raked across	0.90
rough irregular tracked all directions	0.90
seed and fertilizer, fresh	0.64
same after six months	0.54
seed, fertilizer, and 12 months chemical	0.38
not tilled algae crusted	0.01
tilled algae crusted	0.02
compacted fill	1.24 - 1.71
undisturbed except scraped	0.66 - 1.30
scarified only	0.76 - 1.31
sawdust 2 inches deep, disked in	0.61
2. Asphalt emulsion on bare soil	
1250 gallons/acre	0.02
1210 gallons/acre	0.01 - 0.019
605 gallons/acre	0.14 - 0.57
302 gallons/acre	0.28 - 0.60
151 gallons/acre	0.65 - 0.70
3. Dust binder	
605 gallons/acre	1.05
1210 gallons/acre	0.29 - 0.78
4. Other chemicals	
1000 lb. fiber Glass Roving with 60-150 gallons asphalt emulsion/acre	0.01 - 0.05
Aquatain	0.68
Aerospray 70, 10 percent cover	0.94
Curasol AE	0.30 - 0.48
Petroset SB	0.40 - 0.66
PVA	0.71 - 0.90
Terra-Tack	0.66
Wood fiber slurry, 1000 lb/acre fresh ^b	0.05
Wood fiber slurry, 1400 lb/acre fresh ^b	0.01 - 0.02
Wood fiber slurry, 3500 lb/acre fresh ^b	0.10
5. Seedings	
temporary, 0 to 60 days	0.40
temporary, after 60 days	0.05
permanent, 0 to 60 days	0.40
permanent, 2 to 12 months	0.05
permanent, after 12 months	0.01
6. Brush	
7. Excelsior blanket with plastic net	0.04 - 0.10

^aNote the variation in values of VM factors reported by different researchers for the same measures. References containing details of research which produced these VM values are included in NCHRP Project 16-3 report, "Erosion Control During Highway Construction, Vol. III. Bibliography of Water and Wind Erosion Control References," Transportation Research Board, 2101 Constitution Avenue, Washington, DC 20418.

^bThis material is commonly referred to as hydromulch.